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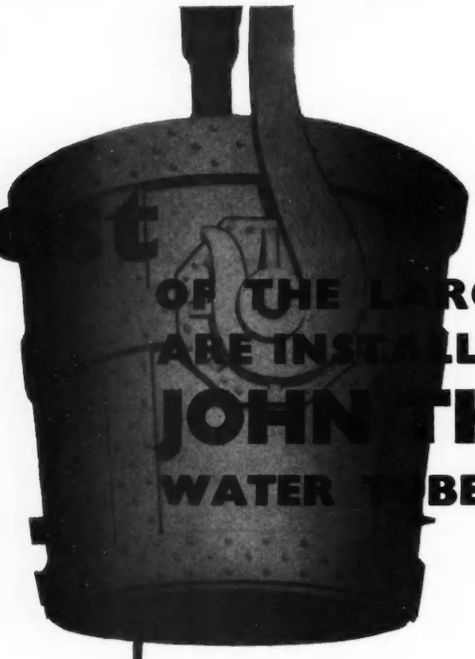

M[illegible]

OF THE L[illegible]RGE STEEL FIRMS ARE INST[illegible]LLING

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WATER T[illegible]BE BOILERS

2,500,000 lb.
STEAM PER HOUR
is being generated at this moment from John Thompson Boilers in Steelworks in this country.

DORMAN LONG & CO.
Three boilers (first contract) and one boiler (repeat order) now steaming, with a second repeat order under erection. Each boiler 100,000 lb./hr. normal evaporation, 125,000 lb./hr. M.C.R.; working pressure 450 lb./sq. in.

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APPLEBY-FRODINGHAM
Three boilers in course of erection, each 85,000 lb./hr. evaporation; working pressure 450 lb./sq. in.

STEEL COMPANY OF WALES
We have recently installed three John Thompson —La Mont boilers, each 38,500 lb./hr. evaporation, and three other John Thompson—La Mont boilers each 10,000 lb./hr. evaporation; all at 175 lb./sq. in. working pressure.

STEWARTS AND LLOYDS
Two boilers in course of erection each 75,000 lb./hr. evaporation, 450 lb./sq. in. working pressure.

JOHN THOMPSON
Over a Century of Boiler Making

WATER TUBE BOILERS LTD.

ETTINGSHALL · WOLVERHAMPTON · STAFFS

WT69

ENGINEERING, MARINE AND WELDING EXHIBITION AT OLYMPIA,

INCORPORATING THE CHEMICAL PLANT EXHIBITION.

(*Continued from page 297.*)

THIS is the third article devoted to exhibits at the Engineering, Marine and Welding Exhibition, which opened at Olympia, London, last Thursday, September 3, and remains open (except on Sundays) until the evening of Thursday, September 17. The exhibits of the first two firms referred to in this article are not illustrated, but in all other cases the exhibits described are illustrated on the following pages and on Plates XIX to XXII.

SMALL INDUSTRIAL GAS TURBINES AND COMPRESSORS.

For the first time in this country, examples of the Turboméca range of industrial gas turbines and compressors, which are being manufactured by Blackburn and General Aircraft, Limited, Brough, East Yorkshire, are shown at an exhibition. The machines on view are a Palouste compressor, with a capacity of 139 lb. per minute at 41·2 lb. per square inch gauge pressure; an Artouste shaft turbine developing a maximum continuous power of 226 h.p.; and a Turmo shaft turbine developing a maximum continuous power of 235 h.p. The Palouste and Artouste machines were described on page 801 of our 175th volume (June 26, 1953). The Turmo turbine is basically an Artouste, with a single-stage compressor-turbine combination, followed by a free turbine which drives the output shaft through a compound planet reduction gear giving a maximum output r.p.m. of 3,500.

The Palouste has been used for two trial operations in the United Kingdom. Coupled to a Jacobs pump, the combined unit has delivered 3,000 gallons of water a minute when on test at Jarrow. The other trial was in controlling sea waves at the lock entry for the British Railways train ferry in Dover Harbour. By bubbling up a wall of compressed air from the floor of the lock, a 4-ft. swell was reduced to 2 ft. A working model of this installation is on view at Olympia.

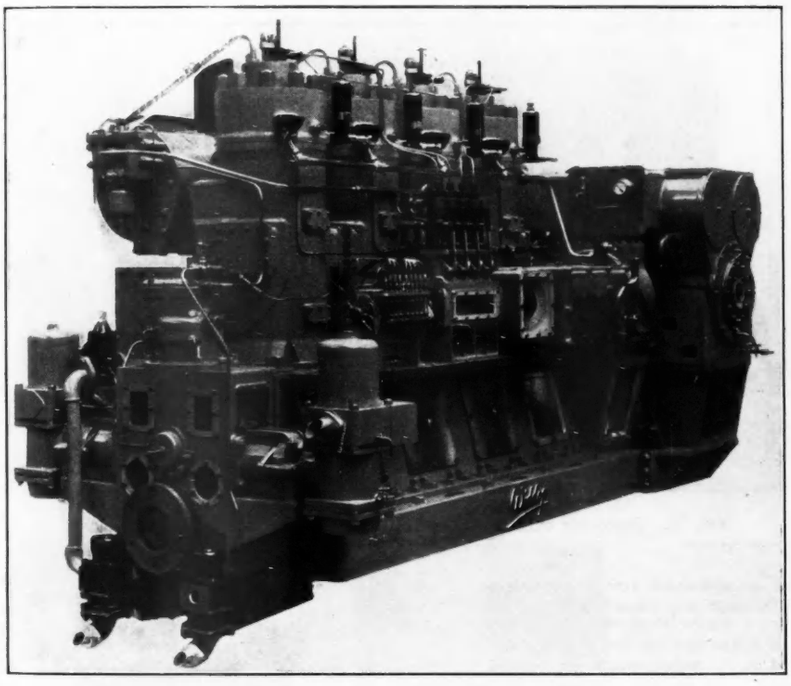


FIG. 71A. 440-S.H.P. MARINE DIESEL ENGINE; H. WIDDOP & CO., LTD.

GRID-CONTROLLED MERCURY-ARC RECTIFIER.

The Nevelin Electric Company, Limited, Purley Way, Croydon, Surrey, are co-operating with their associated companies of the Lancashire Dynamo Group in a display of the products of the constituent concerns. The main feature of the Nevelin exhibit itself is a grid-controlled mercury-arc rectifier which has been arranged to demonstrate how the direct-current output voltage can be automatically stabilised when the alternating-current supply conditions and load are varying. The principle adopted to obtain this result is to use static magnetic control gear to vary the firing angle, and consequently the output voltage, of the rectifier. Only a small direct-current is necessary for this purpose, the value of the control voltage being a function of the difference between the actual and pre-set values of the output voltage. The resulting control current is then supplied to a phase-shifting unit.

The grid control or phase-shifting unit, which may be of the three-phase or six-phase type, consists of three transformers with cores of nickel-iron alloy, which have the property of passing rapidly from the unsaturated to the saturated state when the ampere-turns are increased above a critical value. They are provided with one primary and two secondary windings, one of the latter being designed for control purposes. The primaries of these transformers are connected to adjustable resistors through reactors, the cores of the latter being of silicon iron so that the change from the unsaturated to the saturated state occurs gradually as the ampere turns are increased. The result is that a current of triangular waveform is produced when a sinusoidal voltage is applied to the alternating-current input terminals. A maximum phase-shift of about 135 electrical degrees results when the duration of the secondary peak of the transformers is 30 deg., and the position of the voltage peak depends on the direction and magnitude of the direct current in the control windings of the transformers. The inductance of the control circuit is increased so that the current induced in it does not interfere with the control current, while steps are also taken to eliminate the effect of any ripple. The circuit is biased so that it is unnecessary to reverse the direction of the control current to cover the full range of phase shift; in practice the value of the control current varies from 0 to 300 milliamperes at a maximum of 100 volts.

The magnetic control unit consists essentially of a transductor, the output from which depends upon the flux of two windings. One of these is a reference winding, which is supplied from a potentiometer. This potentiometer is used to adjust the voltage level and carries a substantially constant current which is controlled by a barretter. The current through the reference winding is therefore also constant, its value depending upon the setting of the potentiometer. The second, or signal, winding carries a current which is proportional to the output voltage of the rectifier. The control circuit is arranged so that the tendency is for the ampere-turns of both windings to be equalised, the residual flux being thus reduced to zero. The rectifier grid-control unit and the magnetic amplifier with its comparator transductor together form a complete servo loop. The output voltage is reasonably independent of load fluctuations and variations in the alternating-current supply voltage, the delay in anode firing being adjusted automatically to compensate for such conditions. Inherently, the system described has a rapid rate of response, but to avoid hunting and to limit the transient current taken from the rectifier the rate of change of the signal current can be slowed down, thus increasing the time taken to restore the direct-current voltage to its nominal value.

The standard equipment just described will maintain the output voltage to within ± 1 per cent. of the pre-set value when the alternating-current voltage is constant and the load is varying from zero to full. When the supply voltage is varying by ± 10 per cent., the output voltage is maintained within ± 2 per cent., with a constant direct-current load. A higher accuracy is possible when the equipment is designed for one output voltage only.

At the exhibition, the incoming three-phase supply at 415 volts is passed through a Foster regulating transformer so that the input voltage to the rectifier can be varied over a wide range. The rectifier transformer is of the three/six phase oil-immersed type and feeds a six-tube Nevitron rectifier, which is housed in the same cubicle as the automatic control gear, the cooling fan and the high-rupturing-capacity anode and auxiliary fuses. The output voltage of the rectifier is used to supply two direct-current variable-speed Lancashire Dynamo and Crypto motors, which have been designed to operate in approximate synchronism, even when their loads differ considerably.

440-S.H.P. MARINE DIESEL ENGINE.

The GMB-4 marine Diesel engine shown in Fig. 71A, on this page, is being displayed for the

first time by Associated British Engineering, Limited, Duke's-court, Duke-street, London, S.W.1. It is made by H. Widdop and Company, Limited, Keighley, Yorkshire, and is one of their GMB range of engines designed for use in ocean-going vessels. The engine operates on the two-stroke cycle, develops 440 s.h.p. at 300 r.p.m. and utilises pressure scavenging. The largest of the range of engines develops 880 s.h.p. The bedplate of the engine is of cast iron; the crankcase, which is a single casting, is dowelled and held by tie-bolts. The cylinders are single castings incorporating water jackets and they are bolted directly on to the crankcase. The crankshaft is machined from a forging of open-hearth acid steel of 30-35 tons tensile, and the connecting rods are machined from solid, 28-32 tons tensile, steel forgings.

The large-end bearings are solid gun-metal castings made in two halves, lined with white-metal, and bolted to the flat foot of the connecting rod. The main bearings consist of steel shells lined with white-metal, and the small-end bushes are of phosphor bronze. All the bearing pressures are said to be extremely low. The pistons are made from cast iron and cooled by oil from the main lubricating system. The cylinder heads are steel castings with conical combustion chambers surrounded by a water jacket. The fuel injector is situated in the centre of the cylinder head and is surrounded by a water-cooled spigot. It is fitted with a multi-hole type of nozzle spraying directly on to the head of the piston. High-pressure pumps at the front of the engine supply fuel to the injectors. From full load to 70 per cent. of full load the fuel consumption is between 0·38 and 0·39 lb. per brake horse-power per hour. The exhaust silencer is water-cooled and a secondary silencer of the expansion type is also supplied for mounting in the exhaust pipeline. A single lever controls the operation of starting, stopping, reversing and speed regulation. Other features of the engine include a double-acting piston-type scavenge pump, an air compressor, two plunger-type lubricating pumps operating on the dry-sump principle, a cooling-water plunger pump and a bilge pump similar to the cooling-water pump. Tests on this type of engine are said to have given a lubricating-oil consumption of 0·002 pint per brake horse-power per hour.

Fatigue-Testing Machine.

On the stand of W. and T. Avery, Limited, Soho Foundry, Birmingham, 40, may be seen examples of hardness-testing machines, electro-dynamic balancing machines, and fatigue-testing machines. Their Pulsator dual-mass resonance-type push-pull fatigue-testing machine is illustrated in Fig. 72, herewith. The load is applied by an oscillating system comprising a helcal spring oscillated by an out-of-balance rotor. The machine is operated on the rising portion of the resonance curve, and not on the peak; this avoids exceptionally high sensitivity of load to small frequency changes, and allows the load to be varied while running by regulating the frequency.

A second helical spring is used to apply initial static load to the test specimen, up to 10 tons. The alternating load which can be superimposed on the static load can be varied from $\pm$ 1 ton to $\pm$ 10 tons by the exciter unit. The loads are measured by a loop dynamometer fitted with a microscope, through which the deflection of the dynamometer is measured by an illuminated slot diaphragm and graticule. An amplitude regulator, operating through an electronic relay, controls the frequency and load on the specimen within close limits.

The two loading springs are built concentrically and both are fixed at one end to a loading faceplate supported on vertical struts, having flexible joints, which anchor the oscillating unit to the bed and allow free axial movement of the faceplate. At the end away from the faceplate, the inner spring, which applies static loads, is fitted with an adjusting screw. The outer dynamic-loading spring is freely supported at its end on vertical struts similar to the faceplate supports, and is free to oscillate axially under the forces imposed by the exciter unit. The latter, mounted on the end of the spring, consists of an out-of-balance rotor running on ball and roller bearings, and is totally enclosed. It is driven through a flexible shaft by a direct-current motor housed in the machine bed. A revolution counter geared to the motor records the number of cycles imposed. The specimen is fitted into gripholders, one on the loading faceplate and the other on the dynamometer, which is carried on a bridge which traverses the sides of the bed. The distance between the loading faceplates can be adjusted from 12 in. to 4 ft.

ENGINEERING, MARINE AND WELDING EXHIBITION.

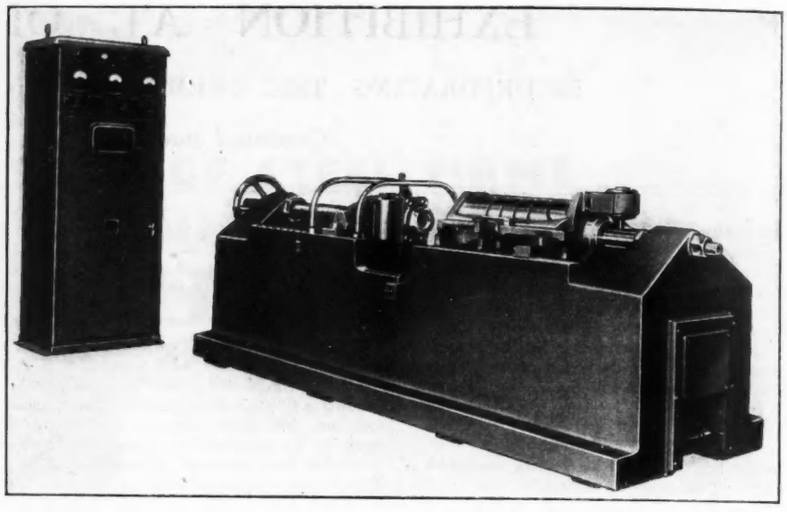


Fig. 72. Fatigue-Testing Machine; W. & T. Avery, Ltd.

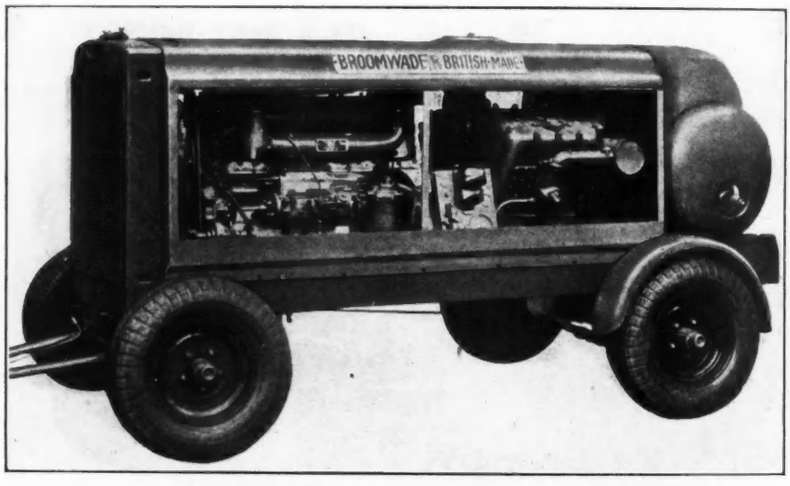


Fig. 73. Portable Sleeve-Valve Air Compressor; Broom & Wade, Ltd.

Portable Sleeve-Valve Air Compressor.

The trailer-mounted sleeve-valve air compressor shown in Fig. 73, herewith, is displayed on the stand of Broom and Wade, Limited, High Wycombe. They are also showing a range of stationary air compressors and pneumatic tools. The machine illustrated, the SV 398, is driven through an automatic Twiflex centrifugal clutch by a six-cylinder Leyland Diesel engine developing 94 brake horse-power at 1,100 r.p.m. The compressor can deliver 320 cub. ft. of free air per minute at a pressure of 100 lb. per square inch. It has four cylinders, with a bore of 6½ in. and a stroke of 4¾ in., arranged in two V-banks, and is fitted with Broom and Wade patented sleeve valves. An air receiver of welded construction, 4 ft. long by 2 ft. 3 in. diameter, is

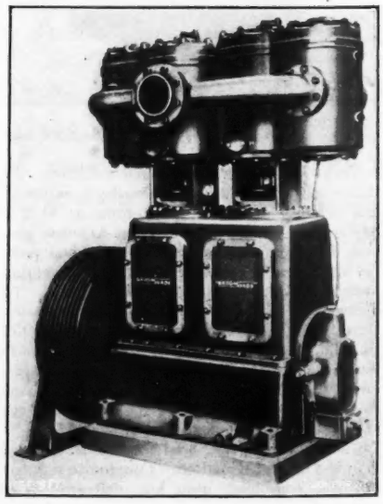


Fig. 74. Oil-Free Air Compressor; Broom & Wade, Ltd.

ENGINEERING, MARINE AND WELDING EXHIBITION AT OLYMPIA.

(*For Description, see Page* 323.)

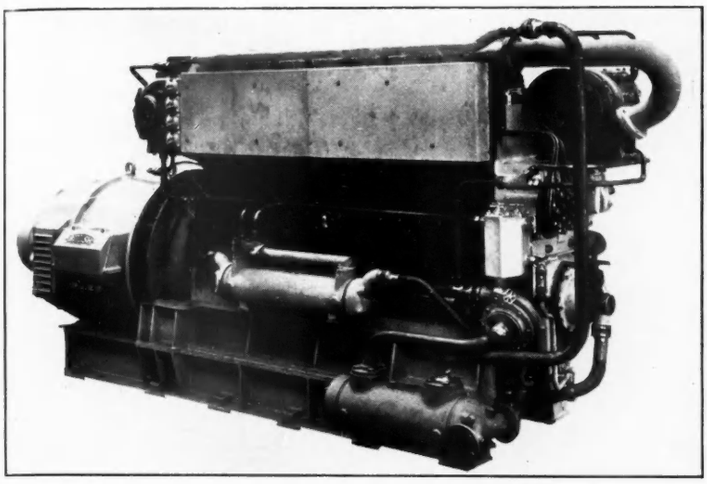


FIG. 75. PRESSURE-CHARGED DIESEL ENGINE AND 208-KW ALTERNATOR; NATIONAL GAS & OIL ENGINE CO., LTD.

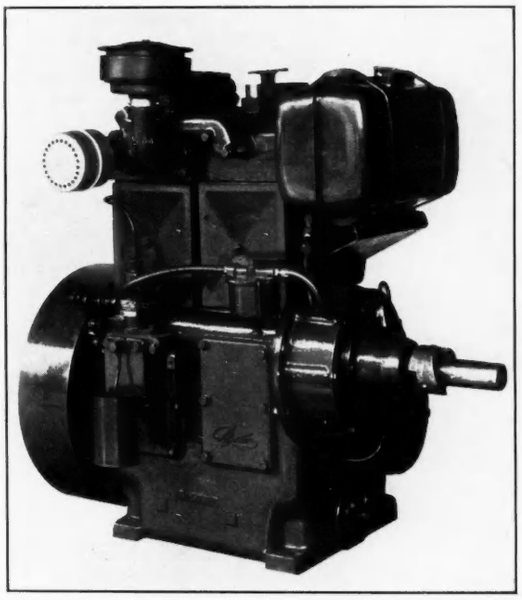


FIG. 77. DIESEL-DRIVEN AIR COMPRESSOR; PETTERS, LTD.

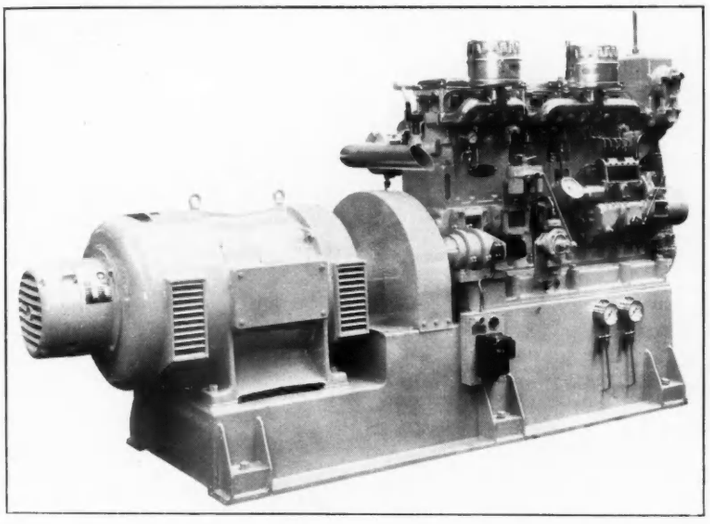


FIG. 76. MARINE AUXILIARY ALTERNATOR SET; J. & H. MCLAREN, LTD.

FIG. 78. MARINE RADAR DISPLAY CONSOLE; COSSOR RADAR, LTD.

FIG. 79. PORTABLE SPOT WELDER; A.R.O. MACHINERY CO., LTD.

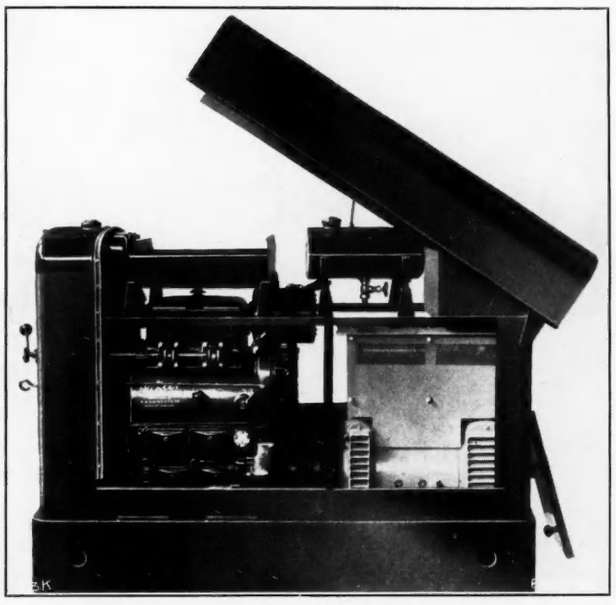


FIG. 80. DIESEL-DRIVEN ARC WELDER; BRITISH TWIN DISC & CLARIFIERS, LTD.

(*To face page* 322.)

ENGINEERING, MARINE AND WELDING EXHIBITION AT OLYMPIA.

(*For Description, see Page 324*)

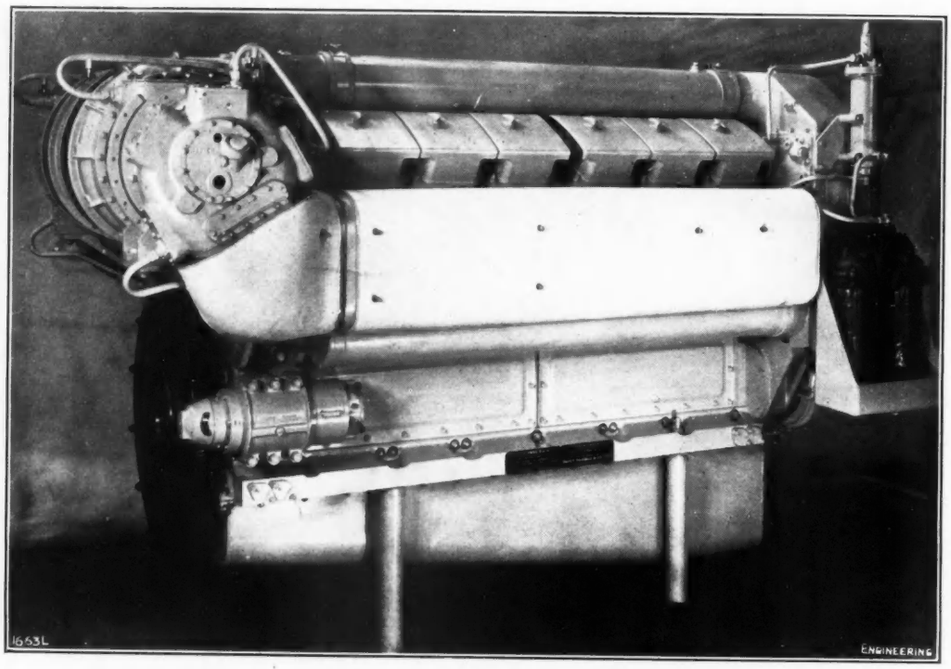


FIG. 81. 800-H.P. PRESSURE-CHARGED DIESEL ENGINE; DAVEY, PAXMAN & CO., LTD.

FIG. 82. HIGH-PRESSURE HAND-OPERATED PUMP; ZWICKY, LTD.

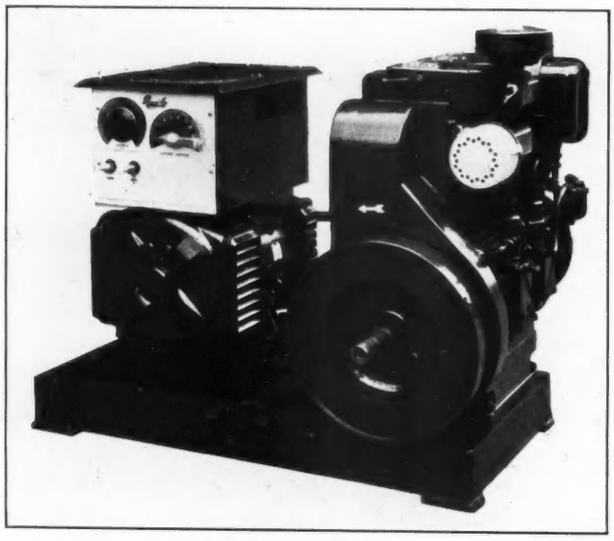


FIG. 83. SINGLE-OPERATOR WELDING MACHINE; QUASI-ARC CO., LTD.

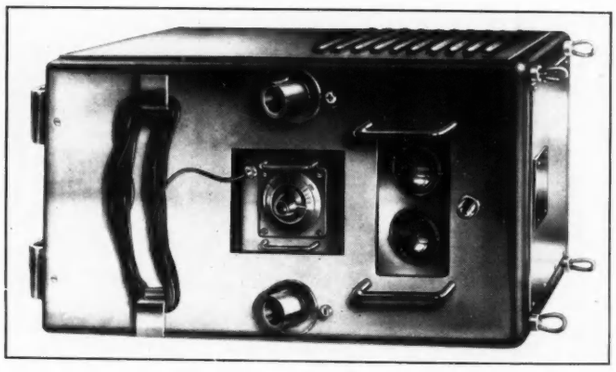


FIG. 84. METAL-RECTIFIER WELDING SET; QUASI-ARC CO., LTD.

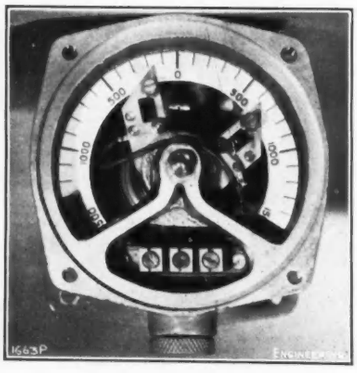


FIG. 85. SPEED-CONTROL SWITCH; SMITHS INDUSTRIAL INSTRUMENTS, LTD.

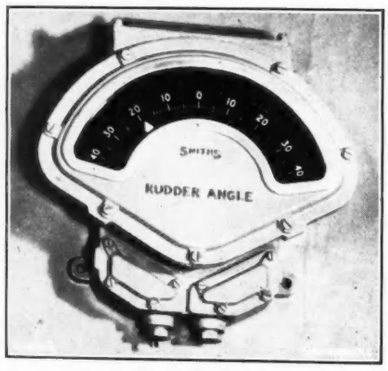


FIG. 86. RUDDER-ANGLE INDICATOR; SMITHS INDUSTRIAL INSTRUMENTS, LTD.

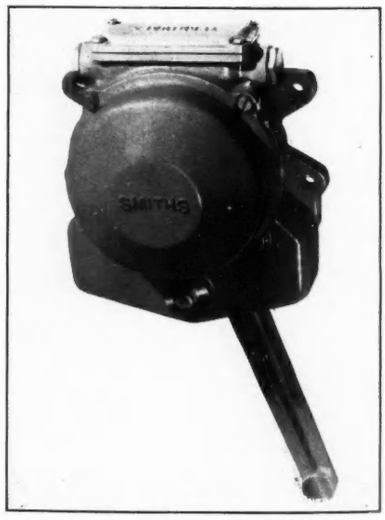


FIG. 87. RUDDER-ANGLE TRANSMITTER; SMITHS INDUSTRIAL INSTRUMENTS, LTD.

(*To face page 323.*)

mounted on the trailer; it has been tested to a pressure of 210 lb. per square inch. An automatic unloader acts when the desired pressure is reached in the receiver; at the same time, the engine speed is reduced by operating the engine control. The speed is automatically restored and full load is taken up by the compressor when the air-receiver pressure has dropped by a predetermined amount.

Oil-bath air cleaners are fitted to the compressor and engine air intakes. Cooling water is supplied to the engine and compressor by a water pump; a large radiator cooled by a pressed-steel fan is incorporated in the cooling system. Forced lubrication is provided by a valveless plunger pump driven from the crankshaft. The chassis on which the unit is mounted has a rigid steel frame, with sprung axles and a tow bar. Internal-expanding brakes are fitted on the pneumatic-tyred wheels, with a connection for a remote-control cable, and a hand parking brake is also provided.

Fig. 74, opposite, illustrates another Broom and Wade exhibit—a single-stage two-cylinder double-acting oil-free compressor, in which the pistons are fitted with carbon rings and require no lubrication. The piston is mounted on a non-corrosive piston rod, and the cylinder bores are lined with a non-corrosive alloy, ground to a mirror finish. The piston-rod gland is also fitted with carbon sealing rings. The machine on view can deliver 1,080 cub. ft. of free air per minute at 20 lb. per square inch, or 790 cub. ft. of free air per minute at 60 lb. per square inch. There is provision for direct drive or V-belt drive.

Pressure-Charged Diesel Engine and 208-KW Alternator.

A wide range of marine propulsion units and auxiliary sets is on view on the stand of the Brush Group, displayed by four of the Group companies—Petters, Limited, Staines, Middlesex; Mirrlees, Bickerton and Day, Limited, Stockport; the National Gas and Oil Engine Company, Limited, Ashton-under-Lyne; and J. and H. McLaren, Limited, Leeds.

Among the exhibits of the National Gas and Oil Engine Company, Limited, is their M4AU8 eight-cylinder pressure-charged four-stroke Diesel engine developing 306 brake horse-power at 1,000 r.p.m., and coupled to a flange-mounted 50-cycle three-phase Brush alternator developing 208 kW at 400-440 volts. This set is illustrated in Fig. 75, Plate XIX. The use of an exhaust-driven turbo-blower results in a useful increase of power with a negligible increase in size and weight. An economical fuel consumption is obtained at all loads, ranging from 0·375 lb. per brake horse-power per hour at full load to 0·4 lb. per brake horse-power per hour at half load; the consumption of lubricating oil and the amount of cooling water used are also less, it is stated, than on a normal engine of the same power.

The high-duty cast-iron cylinder heads are fitted with two inlet and two exhaust valves, push-rod operated, each set at 45 deg. to the crankshaft axis, alternately, with a separate port to each valve tangential to the cylinder, thereby promoting swirl. A separate fuel-injection pump is fitted to each cylinder. Two camshafts are fitted, one on each side of the engine, each shaft operating one inlet and one exhaust valve of each cylinder. The centrifugal governor and the fuel pumps are mounted on one shaft, and a compressed-air distributor on the other. Close-grained cast-iron cylinder liners, of the wet type, are interchangeable. High-grade aluminium-alloy pistons are fitted, with three compression and two oil-scavenge rings. The connecting rods are H-section stampings of alloy steel. The small-end is forged solid and bored to take a phosphor-bronze bush; the big-end, of the marine type, has a steel-backed shell-type bearing. The crankshaft, of cast iron or nickel steel, is also carried in steel-backed shell-type bearings, one on each side of each crank. A disc-type flywheel is mounted on the driving end of the crankshaft. A Triplex roller chain from the crankshaft drives the two camshafts. A spiral-bevel auxiliary drive is provided from the end of the crankshaft, from which the lubricating-oil pump is driven. The water-cooling system includes a built-in centrifugal pump.

Diesel-Driven Water-Cooled Air Compressor.

Among a range of compression-ignition engines and auxiliary sets displayed by Petters, Limited, Causeway Works, Staines, Middlesex, is the Diesel compressor set, type AV2C, illustrated in Fig. 77, Plate XIX, with a capacity of 15 cub. ft. of free air per minute at a maximum continuous pressure of 100 lb. per square inch, and 8 cub. ft. per minute at an intermittent maximum pressure of 350 lb. per square inch. The rotational speed, controlled by a centrifugal governor, is 1,200 r.p.m. The single-cylinder four-stroke Diesel engine and the separate compression cylinder, both of which have a bore of 80 mm. and a stroke of 110 mm., are bolted to a tunnel-type cast-iron crankcase.

The power cylinder is a water-cooled block with a removable cast-iron wet liner. Direct injection into the hemispherical head of an aluminium-alloy piston is employed. Overhead valves are operated by push rods. There are three compression rings and an oil-scraper ring; the top compression ring is chromium plated. The uncooled cast-iron liner and the cast-iron block of the compression cylinder are interchangeable with those of the power cylinder. The compressor cylinder head, of close-grained cast iron, is water-cooled. Again, an aluminium-alloy piston is employed, with a chromium-plated compression ring and two oil-scraper rings. The crankshaft is a two-throw three-bearing alloy-steel forging, running in whitemetal-lined steel-backed thin-shell bearings. Water circulation is maintained by a thermo-syphon, the water inlet being into the bottom of the power cylinder, and into the compressor cylinder head. The outlet manifold is at the top of both cylinder heads. An oil-washed air filter is fitted to the power cylinder and a heavy-duty dry air filter is provided on the compressor air inlet. For starting, which is carried out manually, a hand-operated unloader valve is fitted to the compressor cylinder head, and a decompressor is fitted to the power cylinder.

Marine Auxiliary Alternator Set.

J. and H. McLaren, Limited, Airedale Works, Leeds, are showing the marine Diesel set illustrated in Fig. 76, Plate XIX, with a cut-away head and sump to show the moving parts. The unit comprises a five-cylinder McLaren 110-h.p. Diesel engine flexibly coupled to a Brush 50-cycle three-phase four-wire alternator giving an output of 70 kW at 400-440 volts, with a full-load current, at maximum kVA and 400 volts, of 126 amperes. The alternator is of the enclosed ventilated drip-proof salient-pole rotating-field type; the over-hung exciter is integral with the alternator.

The McLaren Diesel engine operates at 1,000 r.p.m., with a mean piston speed of 1,300 ft. per minute. It has a bore of 5$\frac{3}{16}$ in. and a stroke of 7·9 in. The compression pressure is 480 lb. per square inch, and the maximum pressure 900 lb. per square inch. The exhaust temperature at full load is 750 deg. F. The fuel consumption is 0·6 lb. per kilowatt-hour at full load, 0·73 lb. per kilowatt-hour at three-quarters load, and 0·63 lb. per kilowatt-hour at half load. The consumption of lubricating oil is 0·441 pint per hour. The fuel pump is of the Simms Mono-block type. Heat-exchanger cooling is employed and electric starting is provided. The McLaren company are also showing six-cylinder and three-cylinder marine propulsion Diesel engines.

Marine Radar Display Console.

The marine radar equipment exhibited on the stand of Cossor Radar, Limited, Highbury-grove, London, N.5, consists of a main rack, which contains the transmitter-receiver and other electronic units; a display console, which is illustrated in Fig. 78, Plate XIX; a scanner, and a motor-alternator which is supplied from the ship's direct-current mains and generates alternating current at a frequency of 500. The transmitter consists of a magnetron which is pulse-modulated by a delay-line type modulator to produce a pulse with a peak value of 22 kV, the operating frequency being about 10,000 megacycles. The outgoing signal is fed to the rotating scanner through a length of wave-guide, a small sample of the transmitted pulse being taken to automatic frequency-control circuits to maintain the receiver in tune with the transmitter. If, for any reason, the transmitter becomes so far out of tune with the receiver that the normal control circuit cannot operate, another circuit comes into operation and sweeps the receiver over a wide band of frequencies. This action continues until the correct frequency is found, when the normal control again takes over and the search circuits are shut down.

The signals reflected from the target return to the scanner and down the wave-guide to the receiver, which is protected from the powerful transmitted pulse by a TR cell. The 10,000-megacycle received signals are converted to an intermediate frequency of 45 megacycles at the mixer, which beats the signal with the output of a Klystron local oscillator in a silicon-crystal diode. The 45-megacycle signals are then amplified and fed over a coaxial line to the display console, where they are further amplified, demodulated and applied to a cathode-ray tube. The sensitivity of the intermediate frequency amplifier in the transmitter-receiver is made to vary with time so that the large reflections from nearby targets do not overload the receiver. Maximum sensitivity is, however, reached by the time that signals from more remote objects are received.

The wave forms controlling the timing, receiver sensitivity and the production of range rings on the display are generated in a lock unit in the main rack. The timing system includes a feed-back path from the display console to the lock unit, thus ensuring that normally the transmitter fires as the cathode-ray tube sweeps through the centre of the screen. "Expanded-centre" operation on short range is also available, the timing being adjusted to make the transmitter fire later than normal after the spot has passed the centre of the screen and has travelled some way on its sweep. The effect on the picture is to open out the centre, so that the normal "blob" of the transmitter pulse, which shows the ship's position, becomes a ring and the distance between nearby objects is exaggerated. This is valuable when navigating in the narrow confines of, say, a buoyed channel. Another feature of the set is that the pulse length changes automatically with the range, so that at short ranges maximum definition, and at long ranges maximum power, are obtained. The equipment can be tested by an echo box which reflects the transmitted signals down the wave-guide and gives a picture on the cathode-ray tube so that the performance can be gauged. The equipment is kept dry when not in use by direct-current heaters which are disconnected automatically when the set is switched on. At the same time, a supply of cooling air is circulated by a blower.

Portable Spot-Welding Machine.

The A.R.O. Machinery Company, Ltd., 18, Madrid-road, London, S.W.13, are showing a wide range of welding machines, among which is the spot welder illustrated in Fig. 79, Plate XIX. This is a portable gun-type machine comprising two separate units—the arms and the timer—which are connected by a flexible lead. This arrangement leads to a reduction of weight, so that the welding unit can be held in one hand and gives the operator such freedom of movement that it can be used in awkward positions. The 17-kVA welding transformer is enclosed in the head, thus reducing heat and current losses. It is designed to resist damp and a special type of winding is used to reduce heating to a minimum. The secondary is connected to the moving electrode arm by a copper link, the ends of which are silver-plated to avoid the risk of oxidation. The electrode holders are interchangeable and are held in a specially fitted sleeve, from which they can be released by loosening one nut. They are made from pure bright cold-drawn copper and are available in a number of sizes and shapes. The electrodes themselves are secured in the holders by taper pins or cams. They are made of copper-chromium alloy, a material which has a better mechanical resistance at high temperatures

than copper, so that cooling is unnecessary. The pressure at the electrode tips can be varied between 312 and 500 lb. per square inch. When fitted with standard arms the gap between the electrodes is 3½ in; it can be increased to 6½ in. by the use of extensions. The electrodes can thus be inserted behind projections and obstructions. At the rear of the electrode holders is an adjustable compression spring which ensures a constant welding pressure.

Three types of timer can be fitted, one of which is of electromagnetic design and can be set to operate between 0·01 and 0·1 second. The current is automatically switched on when the pressure between the electrodes reaches a pre-set value, and is switched off after a given interval. A thermic energy control is also fitted which facilitates the welding of scaled sheets. Another type of control incorporates a nine-position selector, which is designed for work on thinner gauges than 20 + 20 s.w.g. mild steel. It contains a booster unit which provides extra voltage in the case of insufficient or faulty mains supply. The gun is connected to the timer, which can be placed any distance away, by a four-core flexible rubber cable. This can be changed without dismantling the equipment.

Diesel-Driven Arc Welder.

British Twin Disc and Clarifiers, Limited, Aldwych, London, W.C.2, are showing a number of Diesel-engine driven arc welders, of which a typical example is illustrated in Fig. 80, Plate XIX. The engine is a Lister two-cylinder Diesel unit developing 16 b.h.p. at 1,550 r.p.m.; it is fitted with a centrifugal governor which maintains the "settled" speed variation within 2 per cent. A fully-automatic release limits the overload to 10 per cent., and a heavy flywheel controls the cyclic irregularity to 1 in 10. Starting is facilitated by the provision of dual combustion chambers which also provide the lowest practical rates for normal operation. The engine is coupled to a drip-proof protected compound-wound direct-current generator with a special drooping characteristic, which is rated to give a maximum hand-welding current of 300 amperes. Separate voltage and fine-current control, which can be operated independently of the "click-action" current selector, is provided, an engraved plate being fitted for the guidance of the operator. Both engine and generator are mounted on a fabricated baseplate. The whole unit is enclosed in a pressed-steel housing with detachable side covers.

The same firm are exhibiting examples of their Twin Disc power take-offs for use with internal-combustion engines. These consist of a clutch assembly, the shaft and bearings of which are mounted in a cast-iron housing. This housing can easily be fitted to an engine and the power transmitted to a compressor, a pump, an agricultural or road-making machine.

800-H.P. Pressure-Charged Diesel Engine.

Davey, Paxman and Company, Limited, Colchester, who are using a combined stand with their associates, Ruston and Hornsby, Limited, Lincoln, are showing among their exhibits their 12YHX engine, which is one of their YH series. It is a V-type of Diesel and operates on a four-stroke cycle. The cylinder bore is 7 in. and the stroke 7½ in. Most of the component parts are made from light alloys and a normally-aspirated and a pressure-charged version of this engine are produced. In the latter form, which is illustrated in Fig. 81, Plate XX, the twelve-cylinder unit develops 800 brake horse-power at 1,250 r.p.m. A number of these engines have been ordered by the Admiralty for use in auxiliary drives and for other purposes. The engine itself is basically similar to the Paxman RPH series engine, which is of cast-iron construction and is also being displayed at the Exhibition. Although the engine was designed for operating at 1,500 r.p.m. it will run in most cases at 1,000 r.p.m. The power range is from 200 brake horse-power—the 12-hour rating of the six-cylinder normally-aspirated engine—to 800 brake horse-power with a 12-cylinder supercharged engine running at 1,250 r.p.m. It has been stated that the mechanical efficiency is 81 to 82 per cent., and the fuel consumption about 0·35 lb. per brake horse-power per hour. The exhaust temperature reaches 740 deg. F. at a brake mean effective pressure of 120 lb. per square inch.

The 12-cylinder engine illustrated is fitted with two Napier turbo-blowers driven by the exhaust gases. They are mounted at the rear of the engine on cast-aluminium brackets, supported on the crankcase. The air delivered is at 5 lb. per square inch and it is passed through Serck intercoolers. The fuel pumps are fitted between the two banks of cylinders immediately above the camshaft, from which they are driven. The cylinder heads carry the inlet and exhaust valves, and the valve seats are made from aluminium bronze and are water-cooled. The crankshaft, it has been stated, is the largest yet produced by drop stamping in Great Britain; the makers were the English Steel Corporation. The lubricating-oil pump and twin centrifugal cooling-water pumps are driven off the free end of the crankshaft, by a flexibly-mounted gear train. The engine is mounted on extruded aluminium bearers incorporating resilient rubber mountings; the bearers also support the salt-water pump. The dry weight of the 12-cylinder pressure-charged engine is 7,800 lb., and its overall length is 7 ft. 10 in.

High-Pressure Hand-Operated Pump.

Zwicky, Limited, Slough, Buckinghamshire, are exhibiting the hand-operated pump shown in Fig. 82, Plate XX. It has been designed for use where high discharge pressures are necessary. One typical application for which a number of these pumps are employed is in the engine room of a ship for starting up oil installations. The pump draws oil from the tanks and discharges through a preheater direct to the burners. For this application the pump, cylinder and guide bracket are all manufactured in a hard close-grained cast iron, and the piston rod, valves, etc., are made from a high-class steel. The pump has a bore of 2 in. and a stroke of 2½ in. It is possible without undue exertion to pump by hand against a pressure of 150 lb. per square inch when pumping fuel oil. At this pressure the pump can be operated at about 15 double strokes per minute and delivers at the rate of about 30/35 Imperial gallons per hour, provided no suction lift is required. The pump meets the requirements of the Lloyds survey, the Board of Trade and the Bureau Veritas for use afloat. The suction and discharge connections are flanged, the former being 1 in. bore and the latter ¾ in. A filter for use with this pump is available.

Zwicky, Limited, are also displaying their N.Z. dual-type filters, which are suitable for use with water, petrol and oils. They can be installed in either a vertical or a horizontal position. These filters are all subjected to a test pressure of 100 lb. per square inch and are suitable for insertion in pipelines where a continuous flow of filtered liquid is required. A flat self-cleaning valve incorporated in this unit enables one filter cage to remain in service while the other filter cage is removed for cleaning—an important feature in circuits where the valve arrangement does not permit the supply of filtered liquid to be interrupted. The ability to use both cages in parallel is useful in a lubricating-oil circuit when starting up, with the oil cold and its viscosity relatively high. The filter body is made from a close-grained cast iron, the filter cage from tinned gunmetal, the protecting plate from perforated copper or mild steel, according to the requirements of the unit, and the filtering and supporting cages are both made from Monel metal or phosphor-bronze.

ENGINEERING, MARINE AND WELDING EXHIBITION.

Fig. 88. PLAN VIEW.

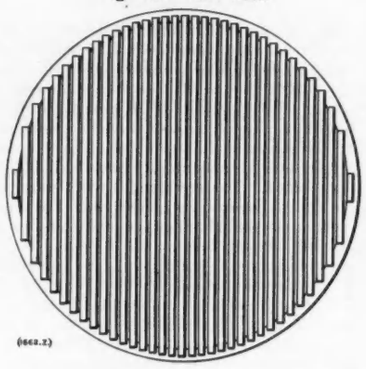
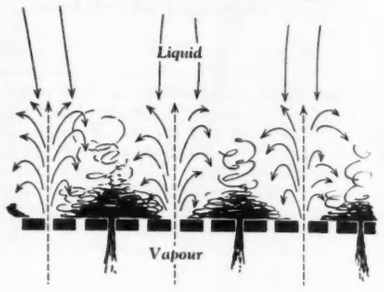


Fig. 89.
SECTION SHOWING GRID TRAY ACTION.



FIGS. 88 & 89. DISTILLATION TRAY FOR FRACTIONATING COLUMNS; W. J. FRASER & CO. LTD.

Metal-Rectifier Welding Machine.

The Quasi-Arc Company, Limited, Bilston, Staffordshire, are exhibiting an addition to their range of direct-current welders. This is intended for welding non-ferrous metals and alloys for which alternating-current plant is not suitable, either because the electrodes available will not operate satisfactorily or because better arc control is needed. This set, which is illustrated in Fig. 83, Plate XX, is interesting from the fact that instead of the usual motor-generator it incorporates a unit consisting of a combined welding transformer, regulator and selenium plate rectifier, which is enclosed in a sheet-steel cabinet with louvres and a fan to ensure adequate cooling. It is designed for connection to a three-phase circuit with an input voltage of from 380 volts to 440 volts. The direct-current output for welding varies from 25 to 375 amperes at an open-circuit voltage of 64 volts, and an arc voltage of 30 volts, infinitely-variable control being provided by a single rheostat, which adjusts the direct-current input from an ancillary rectifier to the magnetic amplifiers. The current selector can be withdrawn from the main plant as a complete unit and used in the working position.

The set is mounted on two steel skids and, as it is remotely controlled, can be housed above or below floor level to save space. It is claimed that the use of a rectifier instead of a motor-generator leads to greater smoothness of welding and ease of striking, while two or more sets can be paralleled at different current settings without damage and without additional equaliser equipment. Both the minimum current and the no-load power consumption are lower than with rotary plant, and the fact that there are no moving parts results in quiet operation and reduced maintenance.

Fig. 84, Plate XX, shows a single-operator Diesel-engine-driven welding set which is exhibited on the same stand. It has been designed to meet the demand which exists, particularly in agricultural areas, for a small low-priced equipment. It consists of a Petter AVA 2 Series II engine with an output of 11 h.p. at 1,650 r.p.m., which drives the generator through four V-belts. These belts are so arranged that the engine pulley can be used as a power take-off for driving small machines. The current range of the generator is from 25 to 180 amperes, and stepless regulation permits the easy deposition of electrodes with diameters from No. 16 to No. 6 s.w.g. Although the set is normally supplied with

ENGINEERING, MARINE AND WELDING EXHIBITION.

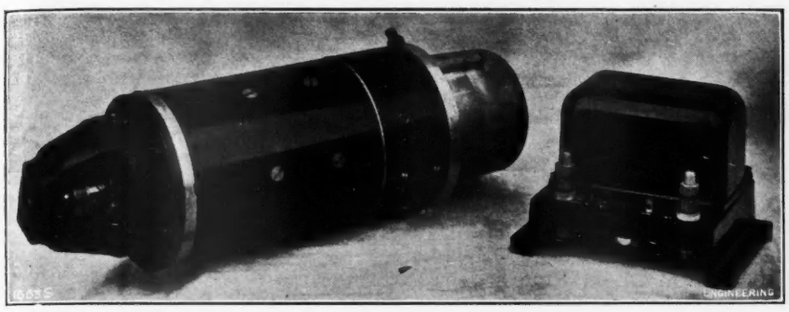


FIG. 90. STARTER FOR OIL ENGINES; C.A.V., LTD.

FIG. 93. PNEUMATIC-DRILL SET; CONSOLIDATED PNEUMATIC TOOL CO., LTD.

FIG. 91. SEARCHLIGHT FOR SHIP'S WHEEL-HOUSE; C.A.V., LTD.

FIG. 92. SEARCHLIGHT FOR MARINE DUTIES; C.A.V., LTD.

four steel locating pins for floor fixing, André rubber mountings can be fitted if required.

"DESYNN" RUDDER-ANGLE INDICATOR.

Among the wide range of instruments that are being exhibited on the stand of Smiths Industrial Instruments, Limited, Cricklewood, London, N.W.2, are hand tachometers for checking the speed of rotation of shafts and other parts; engine service counters for use with light Diesel and petrol engines; and the David Harcourt pressure gauges of the type selected for use on the oxygen bottles carried by members of the Mount Everest Expedition.

Figs. 86 and 87, Plate XX, show the instruments used in the "Desynn" rudder indicator system. Fig. 87 illustrates the transmitter, which has four lugs for bolting it in a position adjacent to the rudder shaft of a vessel. The actuating lever, which projects from the side of the housing and connects with the rudder shaft by a link rod, can be fitted above or below the housing. The mechanism of the instrument is housed in a watertight casting, the top of which can be removed by withdrawing four screws. The terminals are located in a separate watertight pocket and cables enter through cable glands made to the Admiralty pattern. The Desynn system, of which this instrument is a part, is based on two instruments—a transmitter and a receiver; more than one receiver can be used if desired. The system is designed for a 24-volt direct-current supply, and by using a resistance a ship's current can be made suitable. The transmitter houses a toroidal resistance about which a negative and positive brush rotate, the movement of the brushes being caused by any movement of the rudder; this causes the field set up in the stator winding of the receiving instrument to rotate similarly. The receiver contains a rotor in the form of a cylindrical magnet, which follows this moving field in the stator, and the indicator of the instrument is coupled to the rotor. One of the receiving indicators that can be used with this system is shown in Fig. 86, Plate XX. It is designed for mounting on a bulkhead and has the equivalent of a 10 in. dial, which can be illuminated. The intensity of the light can be controlled by a variable resistance.

A speed-control switch shown by the same firm is suitable for a number of applications in industry. An illustration of this instrument is given in Fig. 85, Plate XX. It has been designed to react sensitively to the speed of the shaft to which it is connected. The speed is interpreted by magnetic induction, and the two fingers shown in the illustration are set by hand to the limiting speeds required. Should a speed limit be reached, the switch automatically closes the circuit. Such instruments are used in the control of conveyor-belt speeds, engine governing, winding-speed control or warning on cranes, etc.

DISTILLATION TRAY FOR FRACTIONATING COLUMNS.

On the stand of W. J. Fraser and Company, Limited, Dagenham, Essex, may be seen a new type of distillation tray for fractionating columns, known as the Turbogrid, which, it is claimed, can greatly increase the capacity of oil refineries and chemical installations. The Turbogrid distillation tray was developed by the Shell Oil Company in the United States, and offered by the Shell Group under licence to the oil industry; it has already led to reduced equipment costs and increased production in the Shell refineries. The purpose of distillation trays, which are located at various levels in the fractionating column, is to separate the fractions and to collect those of the same boiling point. The design of the trays and their spacing in the column are important factors in efficient distillation, and the Turbogrid tray is the result of comprehensive development work under widely varied conditions.

As shown in Figs. 88 and 89, opposite, the Turbogrid tray, as produced by the Fraser company, consists of a flat grating extending uniformly over the entire column cross-section. The number and dimensions of the rectangular slats are proportioned to suit the application, and are designed so that the flow of liquid is turbulent, with good vapour-liquid contact. Owing to its ability to allow a straight-through vapour-liquid counterflow in the column, the Turbogrid distillation tray has a greater capacity and a lower pressure drop than the conventional "bubble-cap" tray. For a similar separation efficiency per foot of column height, the capacity of the tray may be up to 100 per cent. more and the pressure drop up to 80 per cent. less than that of a bubble-cap tray. Moreover, servicing and maintenance problems are much simplified.

STARTER FOR OIL ENGINES.

C.A.V., Limited, Acton, London, W.3, are exhibiting a wide variety of their equipment, some of which is designed for marine and industrial engineering application. Fig. 90, herewith, illustrates their S.7-type starter and type-122 solenoid switch. This starter is said to be extremely powerful and was introduced for starting the heavier type of oil engine. It is of the non-axial type and is fitted with a special design of the more familiar starter drive, which employs a moving pinion on a helical thread for engagement with the engine flywheel. This method of engagement has been made possible by using the electromagnetic control switch shown in Fig. 90, mounted apart from the starter, and a trip switch incorporated within the starter. The

control switch provides a two-stage starting sequence. When the starter button is depressed, one section only of the magnetic switch is excited, so that a resistance is connected in series with the starter; this causes a reduced voltage to be fed to the starter, turning the armature and pinion at a low speed. The pinion therefore moves slowly to engage the flywheel and avoids making too great an impact. Towards the end of its travel the pinion closes a trip switch in the starter, which short-circuits the resistance in the control switch; this causes a second winding in the control switch to be excited so that the full starting current flows through the circuit. By this arrangement it is impossible for full torque to be transmitted to the pinion until after engagement with the flywheel, even at low speeds. As a protection against overload a multi-plate clutch is mounted between the pinion and armature shaft.

MARINE SEARCHLIGHTS.

Figs. 91 and 92, on page 325, illustrate two of the searchlights which are included in the exhibits on the stand of C.A.V., Limited. The first is their model No. 1321/A. It has been designed for marine use, has an aperture of 6½ in., is completely waterproof and is made from corrosion-resisting castings as a protection against sea water. The lamp can be rotated through 360 deg. in the horizontal plane, 30 deg. above the horizontal in the vertical plane, and the angle of depression in the vertical plane is 45 deg. It is arranged primarily for mounting through the roof of the wheel-house and being controlled from within. This is achieved by the use of the sleeve-fitting, which can be seen in the illustration, through which the supporting column is actuated by a hand lever. A wing nut is provided for locking the searchlight. The VY107 searchlight shown in Fig. 92 is mounted on a pedestal drilled with three fixing holes. This lamp can also be rotated through 360 deg., plus 20 deg., in the horizontal plane. Over-running is prevented by means of a stop washer fitted in the base of the bracket. Movement in the vertical plane is 45 deg. above or below the horizontal and a large handscrew is provided for locking the lamp in any position. It can be fitted with a 12, 24 or 44-watt bulb. The aperture of the lamp is 6 11/16 in., the outside diameter 7½ in., and the weight 9 lb.

PNEUMATIC-DRILL SET.

Among the exhibits of the Consolidated Pneumatic Tool Company, Limited, 232, Dawes-road, London, S.W.6, are a number of new compressed-air tools, one of which, a pneumatic-drill set, is illustrated in Fig. 93, on page 325. This drill is of the self-rotating percussion type, and the chuck is designed to take rotating drill steels for drilling, and non-rotating chisels for chipping. It weighs only 7½ lb. and has an overall length of under 15 in.; it is supplied with accessories in a metal case. Of interest to the chemical industry is the CP-125 scraper, which is a simple valveless heavy-duty tool, designed for chipping the hard scales often encountered in chemical works. Another valveless tool exhibited is the CP-407 "Triple Scaler," which is designed for a variety of uses, such as the removal of heavy incrustations of rust and paint, stone dressing, and bush hammering.

A new design of sludge pump, to be known as the CP "Double Seven," is also exhibited. This is a compressed-air pump of the ejector type, which creates a vacuum to pick up the water and sludge, which are then ejected by compressed air in a pulsating flow. This pump is said to handle 50 per cent. more water and sludge than the previous model for the same air consumption, and with an air pressure of 90 lb. per square inch it will discharge from 30 gallons per minute against a head of 200 ft. up to 75 gallons at a head of 25 ft.

STRAIGHT-ON STARTER.

Brookhirst Switchgear, Limited, Chester, are exhibiting a range of their standard and specially-designed equipment for motor control in both industrial and marine service. Among these is the "Simple Range" starter illustrated in Fig. 94, Plate XXI. This is of the automatic straight-on type and is intended for the control of a 7½-h.p. 400/440-volt alternating-current motor. This type of starter consists of compactly-designed bulk-produced units, which are enclosed in dust-protecting cases for wall fixing. They can be arranged for local starting and with push-buttons for stopping, for complete remote control by means of push-buttons and for local hand and automatic switching. The ammeter is of the moving-iron type and pilot lamps and fuses are also fitted. Provision is made for locking the isolator in either the "on" or "off" positions, or in both.

Another exhibit on the same stand is the "Comprehensive" straight-on starter for a 27½-h.p. 400/440-volt squirrel-cage motor, shown in Fig. 95, Plate XXI. This starter, which complies with Lloyd's Rules for Electrical Equipment, is totally-enclosed in a drip-proof case with a hinged front lid and is arranged for bulkhead mounting. It comprises a triple-pole main contactor with rolling butt contact which, except in the smallest size, is equipped with magnetic blow-outs and arc shields. Overload trips of either the indirectly-heated type with an ambient temperature compensator or of the solenoid type with oil dash-pot time lags are fitted and in the larger sizes are operated through a current transformer. In either case the trips will open the contactors on sustained overloads, but not on momentary overloads during running nor on normal starting peaks. There is also a no-load release which, in combination with the overload trips, provides a true "free handle" feature. The starter is rated for 40 starts per hour in accordance with the frequent-duty rating of the appropriate British Standard Specification, this being based on the assumption that the short-circuit current of the motor will not exceed six times the full-load current. An isolator is mounted in a closed compartment at the bottom of the case and is interlinked with the main contactor so that the circuit is made and broken by the latter. This isolator is also interlinked with the door of the case. A pilot lamp with a line resistance or condenser is provided to indicate when the motor is running and is also used to illuminate the moving-iron ammeter. This lamp is supplied at 110 volts through a voltage transformer, which also controls the high-rupturing-capacity fuses.

"ALLEY-CLARK" COMPRESSOR.

Two air compressors, a vacuum pump and a high-speed steam engine, are the main exhibits of Alley and MacLellan, Limited, Glasgow, S.2. One of the compressors exhibited is the "Alley-Clark," built under licence, and to the designs of the Clark Brothers Company, Olean, New York, and is primarily intended for use in oil-fields for the compression of natural gas. An Alley-Clark compressor is shown in Fig. 96, Plate XXI. The layout is unusual and resembles an inverted "T": the prime mover is vertical with the scavenging and compressing cylinders extending outwards on both sides of the main crankcase. All the reciprocating mechanism are coupled to a common centrally-located crankshaft. Five models are manufactured, with 2, 4, 6, 8 or 10 cylinders, and powers varying from 85 to 440 h.p., and in all models the cylinder dimensions are the same, with a bore and stroke of 8¼ in. and 8½ in. The scavengers, four of which are shown in the illustration, have a bore of 12 in. and are provided at the rate of one for each pair of cylinders of the main engine; they deliver scavenging air at 3 lb. per square inch. Likewise, the compressors are provided at the rate of one for each pair of cylinders of the main engine. In the model exhibited, which is a four-cylinder 150-h.p. unit, the two compressing cylinders have a bore of 2½ in. and 4 in., and the unit as a whole is stated to be capable of compressing a million cubic feet of natural gas per day, from 265 to 2,015 lb. per square inch.

The other compressor exhibited is the firm's own series 45 B.9 model, which has a capacity of 750 cub. ft. of free air per minute when compressing to 100 lb. per square inch. This machine is a vertical two-stage compressor running at 500 r.p.m. and arranged for direct coupling to a 150-h.p. electric motor. The compressor is double-acting and the pistons are connected through cross-heads and connecting rods, which are of marine design, machined all over and provided with oilways. Force-feed lubrication is provided by a positive pump to all crankshaft, crankpin and cross-head bearings; the cylinders, valves, piston rod and metallic packings receive pressure lubrication from a mechanical lubricator. Machines of this series are available to deal with up to 7,500 cub. ft. of free air per minute, and up to a maximum working pressure of 150 lb. per square inch.

The steam engine exhibited is a high-speed single-cylinder engine running at 600 r.p.m. and developing 77 h.p. This, and other models, were formerly produced by Browett Lindley, Limited, Letchworth, recently absorbed into Alley and MacLellan, Limited.

4-IN. STROKE AIR COMPRESSOR.

Among a range of compressor plant and pneumatic valves and regulators displayed on the stand of Williams and James (Engineers), Limited, Chequers Bridge, Gloucester, are examples of their recently-developed 4-in. stroke air compressors, available as single-stage units with one, two or four cylinders, as illustrated in Fig. 98, Plate XXI, and as two-stage units with two or four cylinders. The maximum pressure developed by the air-cooled single-stage machine is 80 lb. per square inch; by the water-cooled single-stage machines, 125 lb. per square inch; and by the water-cooled two-stage machines, 450 lb. per square inch. The piston displacements range from 17 cub. ft. to 182 cub. ft. per minute for the single-stage compressors, and from 17 cub. ft. to 90 cub. ft. per minute for the two-stage machines. The speed range for all machines is 600 r.p.m. to 1,000 r.p.m., and they can be run in either direction.

On each side of the cast-iron crankcase is a large cover plate which permits easy inspection. The cylinder heads and manifolds, designed to give maximum cooling of the valve assemblies, are in cast iron. The cylinders of the single-stage compressors are in high-quality grey iron; the high-pressure cylinders of the two-stage machines are in high-tensile cast iron. The connecting rods are machined from high-grade steel drop forgings. The big-end bearings are of the steel-backed, white-metal-lined shell type. The small ends, and link connecting-rod bearings on the four-cylinder machines, are steel-backed lead-bronze-lined wrapped bushes.

The crankshaft, of high-tensile cast iron, is accurately balanced and runs in three white-metal-lined steel-backed pre-finished bearings. Separate thrust-bearing washers of high-grade bronze, in the main bearing housings, take the end thrust. Pressure lubrication to the main bearings, big-ends and small ends is provided, at 30 lb. to 35 lb. per square inch, by a plunger pump driven directly from the end of the crankshaft. Adequate lubrication for the cylinder walls is provided by oil thrown from the big-ends; over-oiling is prevented by a piston and ring pack of new design.

Dry fabric air filters are fitted. The valves, of special alloy steel, are of the strip-cushion type and have been designed to eliminate shock and overheating. They provide generous porting, resulting in lower operating temperatures and high efficiency. On the single-stage machines, and the first stage of the two-stage machines, the valves are interchangeable; the second-stage valves are of different size. An automatic unloader, arranged to operate in two stages so that the load is removed and replaced gradually, is controlled by the pressure of the lubricating oil; the compressor is unloaded on the delivery side. On air-cooled machines, a cowling is fitted to ensure a forced draught; water-cooled compressors can be arranged for mains or radiator cooling.

OIL-FREE COMPRESSOR.

Also on view is their oil-free compressor, shown in Fig. 97, Plate XXI. It is designed for continuous operation at speeds up to 350 r.p.m., and is capable of delivering 2·78 cub. ft. of free air per minute at pressures of 40 lb. to 60 lb. per square inch. Owing to the effective cooling, the delivery-air temperature is not more than 35 deg. F. above that of the room in which the compressor is operating. It is a horizontally-opposed two-cylinder machine with a bore of 2½ in. and a stroke of 2 in. To ensure that the air delivered is completely free from oil, the

ENGINEERING, MARINE AND WELDING EXHIBITION AT OLYMPIA.

(*For Description. see Page* 326.)

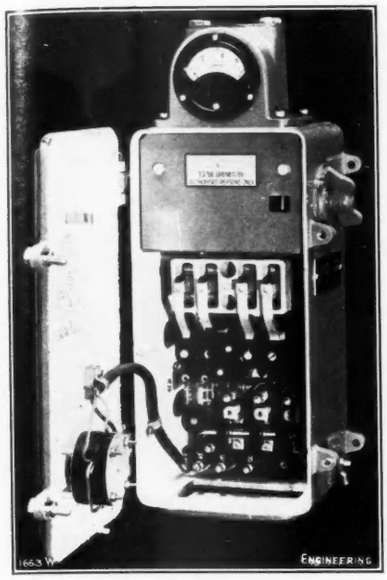


FIG. 94. STRAIGHT-ON STARTER; BROOKHIRST SWITCHGEAR, LTD.

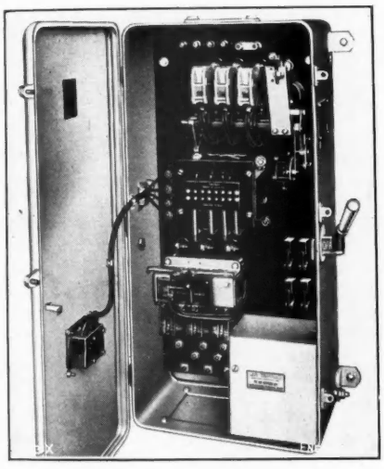


FIG. 95. THREE-PHASE STARTER FOR MARINE USE; BROOKHIRST SWITCHGEAR, LTD.

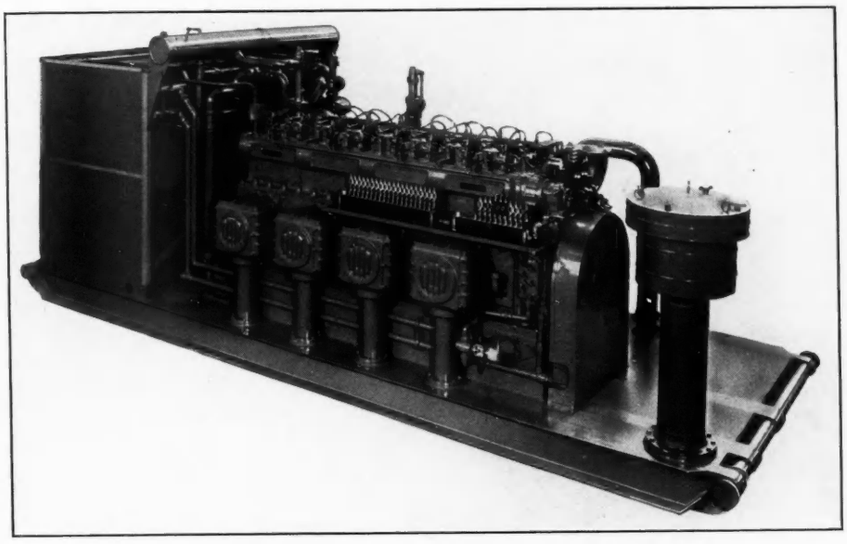


FIG. 96. "ALLEY-CLARK" COMPRESSOR; ALLEY & MACLELLAN, LTD.

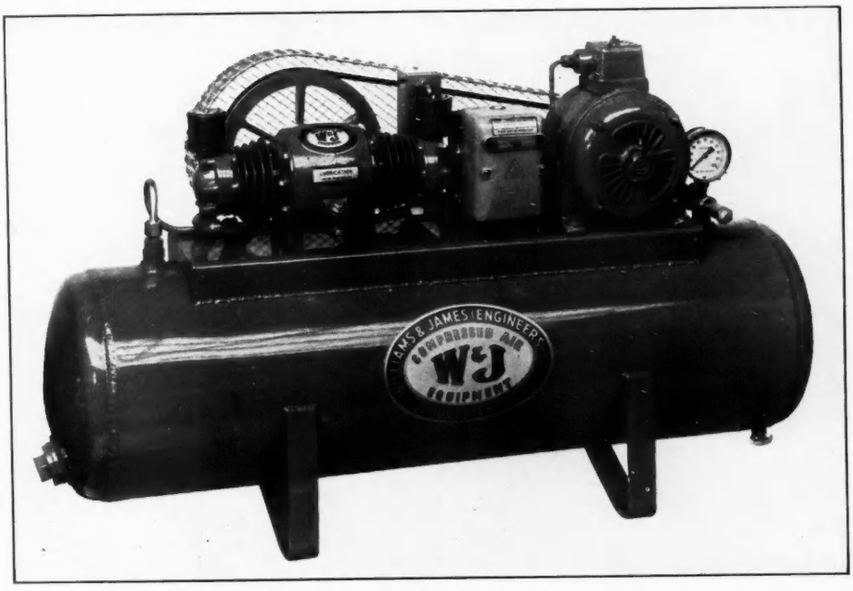


FIG. 97. OIL-FREE COMPRESSOR; WILLIAMS & JAMES (ENGINEERS), LTD.

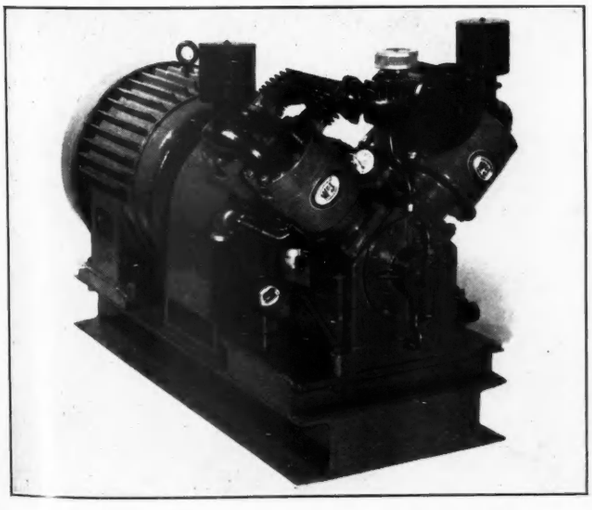


FIG. 98. 4-IN. STROKE AIR COMPRESSOR; WILLIAMS & JAMES (ENGINEERS), LTD.

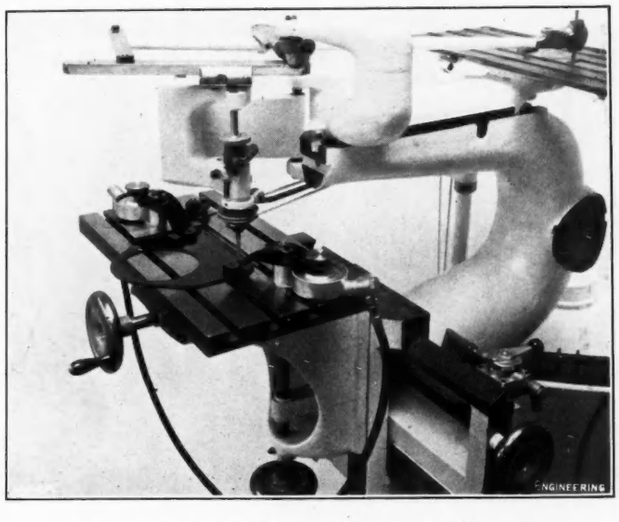


FIG. 99. PNEUMATIC CLAMPING EQUIPMENT; BALDWIN INSTRUMENT CO., LTD.

(*To face page* 326.)

ENGINEERING, MARINE AND WELDING EXHIBITION AT OLYMPIA.

(*For Description, see Page* 327.)

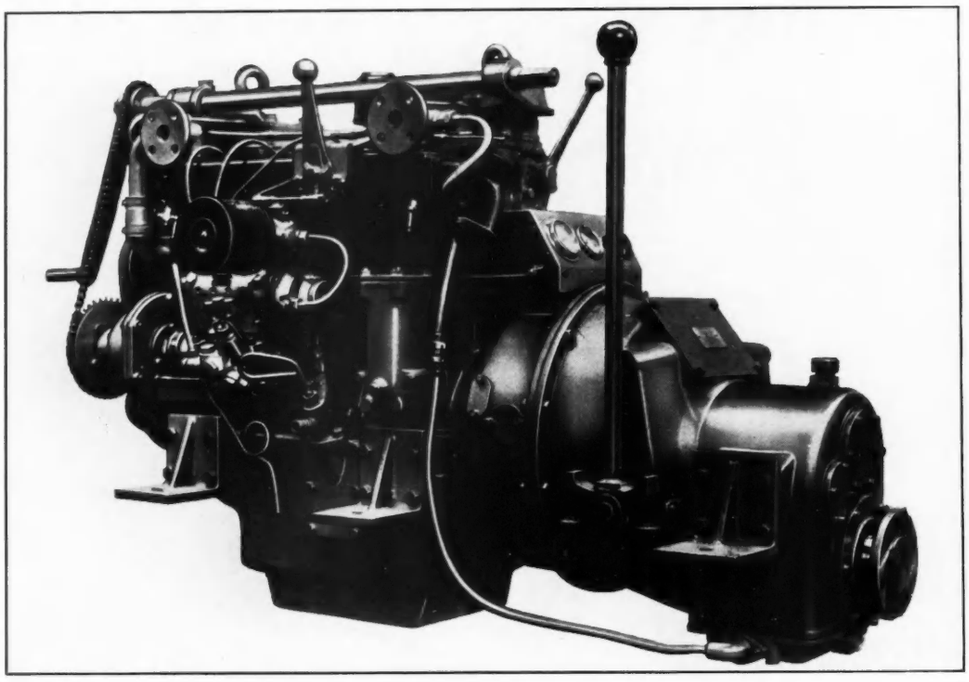


FIG. 100. 32·5-B.H.P. MARINE DIESEL ENGINE; DAVID BROWN TRACTORS, LTD.

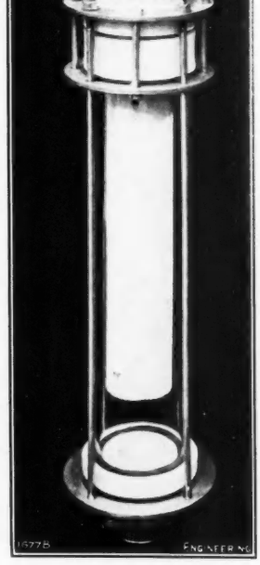


FIG. 101. PIPE-LINE FILTER UNIT; DOULTON & CO., LTD.

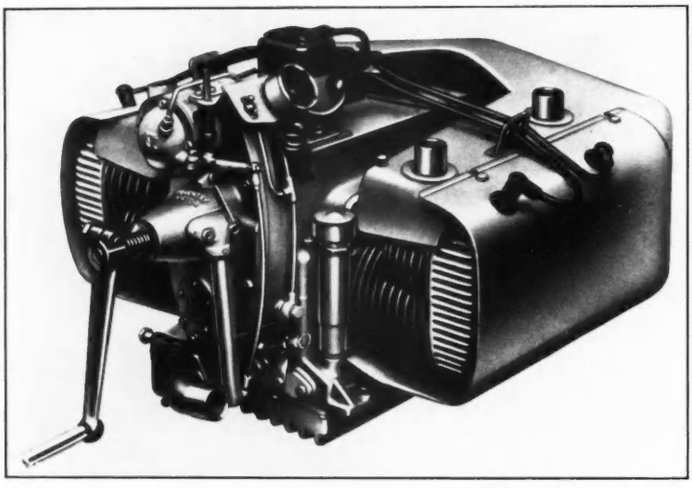


FIG. 102. HORIZONTALLY-OPPOSED PETROL ENGINE; COVENTRY VICTOR MOTOR CO., LTD.

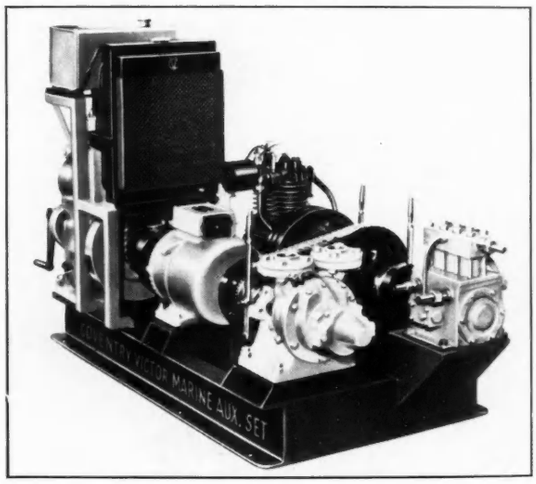


FIG. 103. MARINE AUXILIARY SET; COVENTRY VICTOR MOTOR CO., LTD.

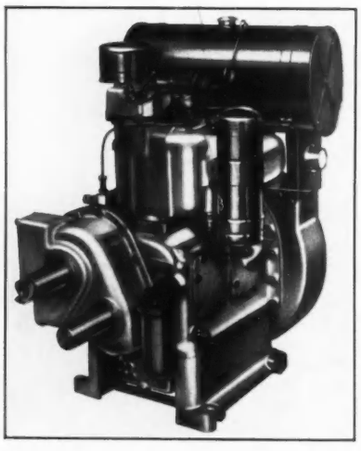


FIG. 104. TWIN-CYLINDER AIR-COOLED DIESEL ENGINE; ARMSTRONG SIDDELEY MOTORS, LTD.

FIG. 105. TOTALLY-ENCLOSED ROTOR STARTER; GEORGE ELLISON, LTD.

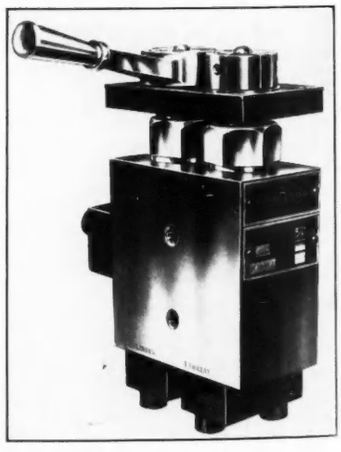


FIG. 106. TWO-WAY HYDRAULIC VALVE; GEORGE ELLISON, LTD.

(*To face page* 327.)

ENGINEERING, MARINE AND WELDING EXHIBITION.

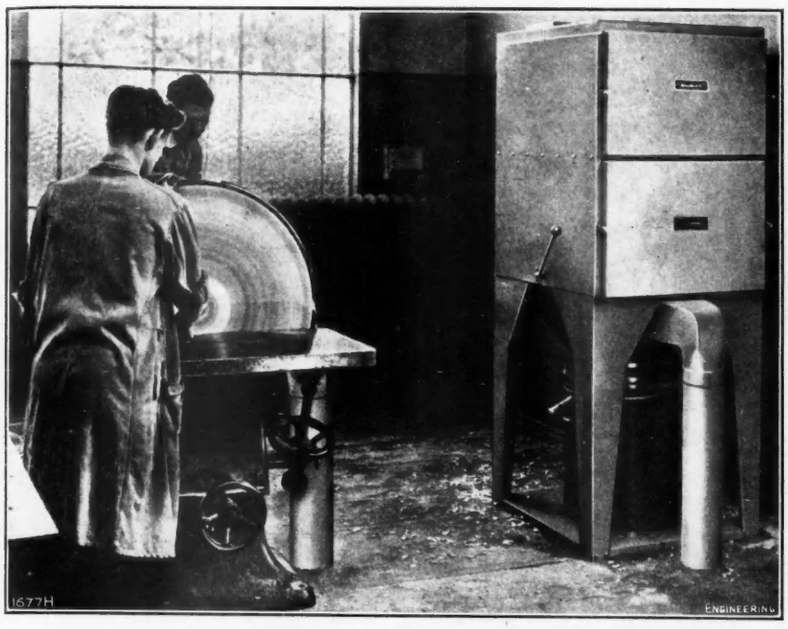


FIG. 107. DUST COLLECTOR IN USE WITH DOUBLE-DISC SANDING MACHINE; DALLOW, LAMBERT & CO., LTD.

machine is designed on the yoke-and-slipper principle, eliminating the necessity for bearings in the cylinder bores. The crankcase is flood-lubricated; to prevent the oil passing into the cylinder bores, two combined bearings and seal housings are incorporated in the crankcase. These bearings, of the steel-backed bronze type, in addition to supporting the yoke, serve to guide the yoke arms. The main bearings are of the ball-journal type. The crankshaft is made from a high-tensile steel forging; the piston assemblies are built up of aluminium components and composite rings which need no lubrication. The cylinders, of nickel cast iron, are finned to give effective cooling; the bores are honed and lined with a hard wear-resisting deposit. The compressors are available as separate units, or as complete automatic plants controlled by a pressure switch which operates on electrical contactors. A solenoid-operated valve ensures that the compressor is unloaded for starting.

PNEUMATIC CLAMPING EQUIPMENT.

A selection of specialised instruments is being exhibited by the Baldwin Instrument Company, Limited, Dartford, Kent, and a new development is their "Pneu-pad" high-speed clamping equipment, which is shown in Fig. 99, Plate XXI, applied to a Taylor Hobson engraving machine. This equipment consists of three main units: the control valve and lever as seen mounted on the right of the machine and just above the traversing hand-wheel; the pneumatically-operated clamp, two of which may be seen fixed to the work-table; and an air-blast unit (not shown in the illustration), which is fixed to the work-table and enables a sharply defined air-blast to be directed to any point for clearing swarf from the work-piece and the surface of the table. The control-value lever has three positions, each separated by 30 deg. of arc. In the illustration, the lever is shown in its control position with all air cut off and the clamps released. Moving the lever to the left causes the clamps to be applied; to the right it both releases the clamp and admits air to the air-blast unit. The clamping arm is a steel pressing with one end rubber-padded, the centre loosely attached to a pillar whose base is cut so that it is held by the work-table slots, and the other end fitted with an adjustable thumb-screw bearing directly on the bellows, which are rigid with the pillar. When air at 80 lb. per square inch is admitted to the bellows, the resulting upward thrust causes a downward load of 170 lb. on the rubber-faced toe. Clamping operations, therefore, are almost instantaneously performed, which results in a saving of time and an increase in production. Also being exhibited is the firm's "Atomat" thickness-measuring instrument, which, by means of beta radiations, will measure the thickness of a moving metal sheet or strip without making any physical contact.

32·5-B.H.P. MARINE DIESEL ENGINE.

Among the exhibits which are being shown on the stand of the David Brown Corporation (Sales), Limited, Meltham, Yorkshire, is the four-cylinder marine Diesel engine, shown in Fig. 100, Plate XXII, recently introduced by them. It is fitted with a David Brown Tractors heavy-duty reversing type of reduction gearbox, giving a choice of 1 : 1, 2 : 1, or 3 : 1 reduction speeds and left or right rotation. The engine is rated at 32·5 brake horse-power at 1,800 r.p.m. and has a continuous rating of 26·5 brake horse-power at 1,600 r.p.m. The stroke is 4 in. and the bore $3\frac{5}{8}$ in., giving a capacity of 165·4 cub. in., and the compression ratio is 16 : 1. The idling speed of the engine is about 700 r.p.m. and its full-load speed range is between 800 and 1,800 r.p.m. The cylinder block and crankcase are chromium-alloy castings, and the wet type of cylinder liner made from a high-grade cast iron is fitted. The crankshaft is forged from a nickel-chromium steel and the main and big-end bearing surfaces are hardened by the Tocco induction-hardening process. There are three main bearings, each having a diameter of 2·25 in., and the end thrust from the crankshaft is taken on the centre bearing. The connecting rods, which are made from manganese-molybdenum steel, are drop forgings and are fitted with steel-backed copper-lead big-end bearings. The diameter of the big-end is 2·12 in. and the width 1·14 in. The pistons are silicon-alloy castings and are fitted with one plain and two stepped compression rings besides the scraper ring. The cylinder head is provided with replaceable valve-seat inserts and copper sleeves for direct injection; the inlet ports are at a tangent to the combustion chamber to create swirl. The fuel-injection equipment includes a C.A.V. injection pump with a pneumatic type of governor, a mechanical lift pump and C.A.V. filters. A geared-type pump submerged in the sump supplies lubricating oil at full pressure to the main bearings and there is an intermittent pressure feed to the valve gear. The relief valve in this circuit is set to operate at 40 lb. per square inch and the filter employed is of the full-flow type; it is fitted with a felt element. A 12-volt motor for starting is fitted as standard and hand starting gear can be added. Cooling is by water, circulated by a gear pump, and the exhaust manifold and reversing box are both water-cooled. The approximate weight of the engine is 1,350 lb.

PIPE-LINE FILTER UNIT.

Doulton and Company, Limited, Doulton House, Albert-embankment, London, S.E.1, are demonstrating a new range of pipe-line filter units, an example of which is illustrated in Fig. 101, Plate XXII. Some years ago, the Royal Doulton Potteries produced a small hard-glass filter unit intended primarily for laboratory or pilot-plant work for filtering both corrosive and non-corrosive liquids under negative or positive pressures. This unit, since adopted in many production processes, is 8 in. long and 1 in. in diameter, and is provided with a glass casing for fitting into a pipeline. As a result of development work, the Royal Doulton Potteries are now able to manufacture larger units of the type illustrated in Fig. 101. Such filters are easily cleaned without disturbing the element, and they have the advantage that the liquids passing through them have no contact with metals. The selection of suitable corrosion-resistant gasket materials presents some problems, but it is hoped that these will be largely overcome by the adoption of polytetrafluoroethylene (P.T.F.E.), on which development work is now under way. A typical unit takes a filter element 18 in. long and $3\frac{1}{2}$ in. in outside diameter, giving an effective surface area of approximately $1\frac{1}{4}$ sq. ft. The element is encased in a glass tube of approximately $4\frac{1}{2}$ in. bore, and has chemical-stoneware inlet and outlet connections at either end. In the unit illustrated, these connections are of the type used in chemical-stoneware fixed-flange piping; alternative types are also made.

MARINE AUXILIARIES.

Some 14 different engines and engine sets, both air-cooled and water-cooled, and both Diesel and petrol driven, are exhibited by the Coventry Victor Motor Company, Limited, Coventry. The Diesel engines shown are the overhead-valve single-cylinder A.D.1 and A.D.2, rated at 4 h.p. and $5\frac{1}{2}$ h.p. at 1,500 r.p.m., respectively, the latter engine being a new addition to the range of engines. These two engines are identical, except for their bores, which are 80 and 85 mm., the stroke in both cases being 100 mm., so giving swept volumes of 502 c.c. (30·7 cub. in.) and 567 c.c. (34·6 cub. in.). The mean effective pressures at full load at 1,500 r.p.m. are 83 and 87 lb. per square inch. The overhead valves are totally enclosed and push-rod operated, and pressure lubrication by a gear pump is provided to all bearings. These air-cooled models are supplemented by three water-cooled versions, the W.D.1, W.D.2, and W.D.3, which, again, have a stroke of 100 mm. and bores of 80, 85 and 90 mm., and are rated at 5, 7 and 9 h.p. at 1,500 r.p.m.; the mean effective pressures of these engines, however, are higher, at 91, 106 and 120 lb. per square inch. The piston speed at 1,500 r.p.m. is, of course, the same for all five models, being 984 ft. per minute. The engines are all sturdily constructed and fully governed; a special governor is also available with a wide range to enable an engine to be run at any desired speed between 800 and 2,000 r.p.m. Fuel consumption at the rated outputs is 0·38 pint per brake horse-power hour, when running on standard grade high-speed Diesel oil. Engines of this type and power range have a variety of uses for lighting and pumping and the driving of agricultural machinery; an interesting application is that depicted in Fig. 103, Plate XXII —a marine auxiliary set, comprising a generator, bilge-pump, air compressor, and steering pump, all of which are powered by a W.D. type of engine and can be individually driven through hand-operated clutches.

HORIZONTALLY-OPPOSED PETROL ENGINE.

Also exhibited are several petrol engines of the horizontally-opposed piston type, which are, therefore, inherently balanced and for all practical purposes vibrationless. The largest engine of this type exhibited is the "flat-four" Neptune, model A.C.4., which is a four-cylinder unit continuously rated at 16/30 h.p. at 1,400/2,500 r.p.m.; the air-cooled version is shown in Fig. 102, Plate XXII. This engine is manufactured for both air and water cooling, and for marine or land use, the water-cooled marine model being the chief exhibit on the firm's stand. These marine models are available with or without forward and reverse and reduction gearboxes, which are supplied, as required, in unit construction with the engine; conversion sets are also made for these engines, enabling them to operate on tractor vaporising oil, which is stated to give a better fuel consumption and, being less expensive, reduces fuel costs by as much as 50 per cent.

Of the same type as the Neptune engine is the type "N" Mark 2, of 6/16 h.p. at 1,400/2,500 r.p.m. This engine is a twin-cylinder horizontally-opposed unit and is made in both water-cooled and air-cooled versions and for land or marine use, with or without gearboxes and equipment to enable tractor vaporising oil to be used as fuel. The smallest opposed-twin exhibited is the "Midget," which, in its air-cooled form, weighs only 60 lb., and has a capacity of only 285 c.c.; the water-cooled model weighs 67 lb. and has a capacity of 340 c.c. Variations of these engines are also being exhibited as outboard motors, rated at 2½/5 h.p. for the air-cooled unit and at 3½/6 h.p. for the water-cooled unit.

TWIN-CYLINDER AIR-COOLED DIESEL ENGINE.

Armstrong-Siddeley Motors, Limited, Coventry, are exhibiting examples, including sectioned models, of new single-cylinder and twin-cylinder air-cooled Diesel engines; an illustration of the 14/20-h.p. twin-cylinder engine is given in Fig. 104, Plate XXII. The cylinder dimensions are square, with a bore and stroke of 4·25 in., giving a swept volume of 60·3 cub. in. (988 c.c.) for the single-cylinder, and of 120·6 cub. in. (1,976 c.c.) for the twin-cylinder engine. Brake horse-power for the two engines varies from 5 h.p. at 900 r.p.m. to 8 h.p. at 1,500 r.p.m. for the single-cylinder engine, and from 14 h.p. at 1,000 r.p.m. to 20 h.p. at 1,500 r.p.m. for the twin-cylinder version; it will be noted that the addition of an identical cylinder raises the output at 1,500 r.p.m. by 2·5 times. The piston speed and the compression ratio are the same for both engines, being 708 ft. per minute at 1,000 r.p.m., and 15 to 1, respectively.

The cylinders and detachable cylinder heads are, of course, identical; they are of high-grade cast iron and deeply finned, and enclosed in a casing through which air is blown by the vaned flywheel. The pistons are of light alloy and in the crowns are formed the hemi-spherical combustion chambers; three compression and two oil-control slotted scraper rings are fitted, the lower oil ring being below the gudgeon pin. The connecting rods are I-section forgings with split big-ends; the bearings of the small-ends are of steel-backed phosphor-bronze, and the bearings of the connecting-rod half of the big-ends are of thin-shell Vandervell indium-lead-bronze; white-metal bearings are fitted to the caps. The crankshafts are machined from solid forgings and are fully balanced, both dynamically and statically, and the main bearings, 2½ in. in diameter, are of steel-backed white-metal. The camshaft is of case-hardened steel and runs in three white-metal bearings in the case of the single-cylinder engines, and in four bearings in the case of the twin-cylinder models; the camshaft in both types of engine protrudes through the crankcase and provides an alternative drive at half engine speed. Starting-dogs for engagement with the engine starting handle are formed at the extreme end of this shaft. Lubrication is through a gear-type pump built into the crankcase, the normal oil pressure being 35-45 lb. per square inch; oil is forced to all main and big-end bearings through the drilled crankshaft, and is taken by external piping to the overhead-valve rocker bearings.

These engines are of sturdy construction and can be used on farm machinery and for lighting and pumping. On the same stand is also shown the "Tetrarch" portable welding set, which is driven by one of these engines and has an output of 300 amperes.

ENGINEERING, MARINE AND WELDING EXHIBITION.

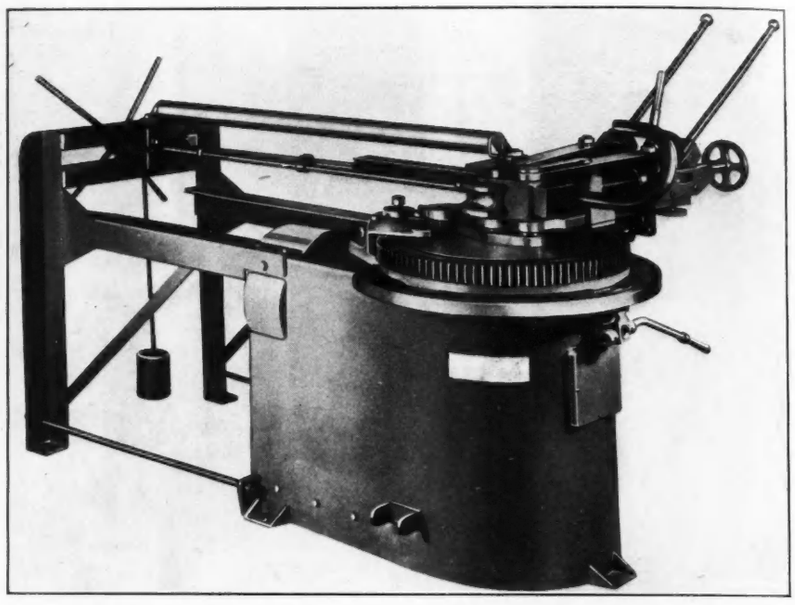


FIG. 103. MACHINE FOR SHORT-RADIUS COLD BENDING OF TUBES; HILMOR, LTD.

TOTALLY-ENCLOSED ROTOR STARTER.

Visitors to the Olympia stand of George Ellison, Limited, Perry Bar, Birmingham, 22B, will have an opportunity of seeing a comprehensive display of switchgear, cable end couplings and fittings and hydraulic control valves. The switchgear includes a rotor starter for slip-ring induction motors, which is made in five sizes for motors up to 1,000 brake horse-power, rotor currents of up to 600 amperes, and slip-ring pressures up to 3·3 kV. These starters, one of which is illustrated in Fig. 105 Plate XXII, are designed for arduous conditions and are provided with a totally-enclosed top as a protection against dust and dirt. There is also a thermostat to prevent overheating. The starters consist essentially of oil-immersed star-connected resistances from which tappings are made to a contact dial, the neutral point being earthed when a connection is made to a terminal on the case. The geared operating handle is designed so that, though there is a definite pause on each contact, the movement between the contacts is rapid. The contact dial is placed under the resistance at the bottom of the tank, where it is in the coolest place and under the highest head of oil. The moving contacts are self-aligning and consist of self-seating copper rollers which are free to swivel on copper ball joints carried on a brass spider. They are forced against the fixed contacts by spring pressure applied so that each roller can surmount a roughness on the dial without reducing the pressure on the others. They can be renewed by turning in a lathe. Generally speaking, the starters are rated for the most usual conditions—that is, for motors driving shop shafting. The stored energy of the shafting and rotor is assumed to be 1,000 ft.-lb. per brake horse-power and the friction torque 60 per cent. of the full-load torque. The starters will pass 100 per cent. peak current on each notch during a total starting time of 30 seconds. They are intended for infrequent starting, and the normal rise in the oil temperature is obtained with one start every 30 minutes in the case of the smallest size and every two hours in the largest. The cooling periods are graded between these extremes in the intermediate sizes. The rise in the temperature of the oil does not exceed 150 deg. F. after three successive starts.

TWO-WAY HYDRAULIC VALVE.

The same firm are showing a two-way hydraulic control valve, the pressure and exhaust units of which are coupled together so that they can be operated by one handle. These valves, an example of which is shown in Fig. 106, Plate XXII, although designed primarily for use on high-pressure water systems, are giving good service where oil is used and work well with machines requiring sensitive control. The bodies are generally made of forged manganese-bronze, while the internal parts are of durable non-corrosive materials, parts liable to wear, such as closure pins and seats, being renewable. They are of the screw-down pattern and are so designed that, when closing, foreign matter passes between the seating faces instead of being embedded and causing scouring. Each time the valve is operated a gentle wiping action occurs between the surfaces, thus helping to reduce maintenance. The operating lever has a short easy movement, which saves time, reduces fatigue, and ensures accurate control and is designed so that it can easily be interlocked with the machine guards.

DUST COLLECTOR.

The new "Dustmaster" dust collector D.M.103, shown in use with a double-disc sanding machine and connected to it by underground ducts in Fig. 107, on page 327, is made by Dallow, Lambert and Company, Limited, Spalding-street, Leicester. They produce this type of collector in three series, D.M.50, D.M.100 and D.M.150, giving filtering areas up to 50 sq. ft., 100 sq. ft. and 150 sq. ft., respectively. Each is available with one of four different size dust collectors varying from 1 cub. ft. to any required volume. There are four inlets on the model illustrated, to which the suction ducts can be attached, one inlet being provided on every side to facilitate installation. The dust-laden air is sucked into the duct and passed to an expansion chamber, where the heavier dust particles settle. The fine dust passes upwards and is filtered by a flameproof fabric pad-type filter mounted in a tensioned frame. The filter assemblies are available with either 11 or 18 pads, and these give filtration areas of 60 sq. ft. or 100 sq. ft. Any one of eight standard fans driven by electric motors of different ratings can be fitted in the collector. They are mounted on the cleaned-air side of the filter and handle from 175 cub. ft. per minute to 2,000 cub. ft. per minute, according to which is chosen. The cleaned air is discharged vertically upwards, and a plain outlet or a silencing type of discharge duc t

"VIPER ASV3" JET ENGINE.

ARMSTRONG SIDDELEY MOTORS, LIMITED, COVENTRY.

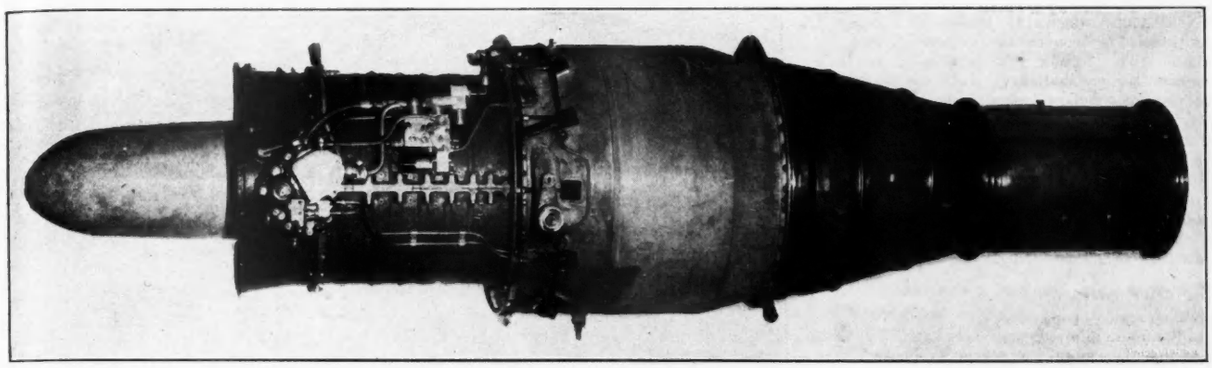


FIG. 1. "VIPER" SHORT-LIFE JET ENGINE.

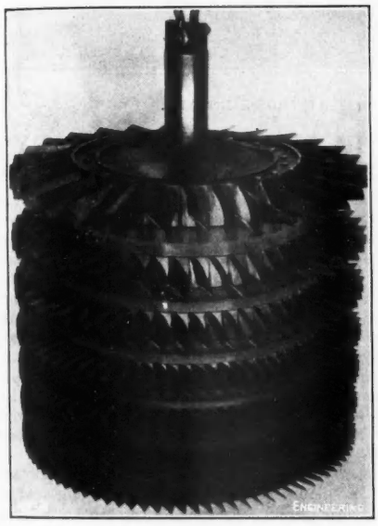


FIG. 2. COMPRESSOR-ROTOR ASSEMBLY.

can be fitted. A hand lever, which may be fitted at either side of the machine and can be seen in the illustration, operates a shaker mechanism, causing the collected dust to fall into a quick-release container; this ensures that the filter is cleared and that its efficiency is maintained. Two of these units can be coupled together and one fan and motor shared between the two.

MACHINE FOR SHORT-RADIUS COLD BENDING OF TUBES.

Hand-operated, hydraulic, and motor-driven tube-bending machines are exhibited by Hilmor, Limited, 65, Calshot-street, London, N.1. A motor-driven mandrel machine, designed for the production of full-bore short-radius bends from cold tube, is illustrated in Fig. 108, opposite. These machines are designed to handle different materials and to produce bends, without filling, from ferrous and non-ferrous tubing of up to 2 in. in diameter. A machine recently introduced is the No. 4 Trap Bender, which is designed to produce waste-traps and siphon-bends in light-gauge non-ferrous tube; this machine is also of the motor-driven mandrel type, and is fitted with hydraulic gear to effect the withdrawal and return of the mandrel, and the ejection of the tube after bending. For this particular machine, extra equipment is made to facilitate the production of one-piece "P" and "S" traps of both deep and shallow seals. The time taken to produce a bend on these machines varies both with the material and type of bend, but an average output of 75 bends an hour is claimed.

(To be continued.)

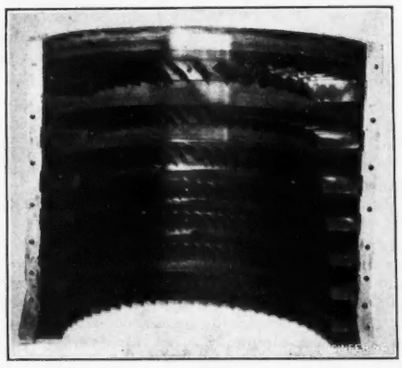


FIG. 3. COMPRESSOR-STATOR HALF-CASING.

"VIPER ASV3" JET ENGINE.

FIG. 1, above, shows the Viper ASV3 "short life" jet engine, designed and constructed by Armstrong Siddeley Motors, Limited, Coventry, which has been on view in the static exhibition at the Society of British Aircraft Constructors' annual display at Farnborough this week. The Viper 3 is now in production for the Australian Jindivik pilotless aircraft. The primary considerations in the design of this expendable engine were simplicity in construction and the use of non-strategic and less costly materials. Originally intended to withstand a life of 10 hours, the performance and durability of the Viper greatly exceeded expectations and, in fact, a standard Viper 3 has satisfactorily completed a normal 150 hours run to type-test conditions. As a result the Viper has aroused interest as a power unit for piloted aircraft, and a "long life" version, the ASV5, is now under development for the Percival Jet Provost training aircraft. The present "short life" Viper 3 has a maximum sea-level static thrust of 1,640 lb. at the 10-minute rating of 13,400 r.p.m., the corresponding jet-pipe temperature being 645 deg. C. The specific fuel consumption at maximum revolutions per minute is 1·09 lb. per lb. thrust per hour. The engine has a net dry weight of 365 lb., an overall length of 65·4 in., not including the generator shown in Fig. 1, and a maximum diameter over the engine casings of 23·35 in.

Security restrictions on the Viper have now been lifted and some constructional details may be given. A section through the Viper 3 is shown in Fig. 4, page 336. The engine comprises a seven-stage axial-flow compressor coupled to a single-stage turbine, with an annular combustion chamber fitted with 24 Armstrong Siddeley vaporising burners which were first developed for the Mamba propeller turbine. A low compression ratio, 3·5 to 1, is employed, and the air mass flow is 30 lb. per second. Primary air leaving the compressor enters the vaporising tubes, which are mounted at the forward end of the flame tube. Fuel pumped at low pressure to the vaporising tubes mixes with the primary air and vaporises, and is ignited at the forward-facing exits of the tubes where it encounters secondary air entering the annulus through holes in the flame-tube back plate. Tertiary air is directed outside the flame tubes and bleeds in through cooling slots in the flame-tube walls; part of the tertiary air also serves to cool the outer face of the turbine stator assembly.

BUILT-UP COMPRESSOR ROTOR.

The most interesting constructional feature of the Viper is probably the fabrication of the compressor rotor (Fig. 2), which consists of a series of separate discs bolted together, with the rotor blades "sandwiched" between them. The front and rear discs, which are integral with the compressor front and rear stub-shafts, are of EN 34 alloy steel. Balancing flanges, from which metal may be removed as required for dynamic balance, are provided on the front and rear discs. The intermediate discs and rotor blades are in aluminium alloy. The method of assembly is as follows: each of the discs has a circumferential groove on each face (excepting the front and rear discs, in which the groove is on one side only), corresponding with the groove on the adjacent disc face. The individual blades, the roots of which are slotted to form tongues, are held between these grooves. The procedure is to lay the front disc face down on the bench, and after filling the groove with Marco resin, to insert the first-stage rotor blades, then to assemble the first intermediate disc, and to bolt up the assembly with 2 BA studs and self-locking nuts. The second-stage blades are then inserted in the groove on the rear face of the first intermediate disc, in the same manner, and the process is repeated.

The compressor and turbine-rotor assembly is carried in three Hoffmann bearings; the front stub-shaft runs in a ball thrust bearing, housed in the rear face of the air-intake casing. The rear stub-shaft, into which the hollow turbine shaft is splined and retained with a lock nut, runs in a central roller bearing, housed in the forward end of the combustion-chamber casing; at the rear end, the turbine shaft runs in a roller bearing also mounted in the combustion-chamber casing. Each bearing is lubricated by a microfeed supplying ½ pint of oil per hour. The front bearing is not cooled, but the centre and rear bearings are air-cooled by air from the final compressor stage, which enters through an axial gap between the last row of rotor and stator blading. After passing through and over the central bearing, the air travels down the centre of the combustion chamber housing to the rear bearing and the front of the

turbine-rotor disc. The rear face of the turbine disc is cooled by air drawn through holes in the sixth compressor disc, which passes into the compressor drum and through the hollow turbine shaft.

The turbine comprises an austenitic-steel disc, in EN19T, into which 113 blades of Rex 467 austenitic steel are conventionally fixed by fir-tree serrations. The turbine disc is coupled to the hollow-steel turbine shaft by a Hirth coupling and is retained by a hollow locknut. At the forward end of the compressor rotor assembly, an internal gear, mounted in the inner ring of the air-intake casing, provides a drive for an electrical generator, and, through a bevel drive, for the fuel and oil pumps. The latter drive shaft passes through one of three hollow struts which serve to join the inner ring of the air-intake casing (which is a magnesium-alloy casting) to the outer ring.

Stators and Combustion Chambers.

The compressor casing comprises two half-cylindrical aluminium-alloy castings bolted together on their common horizontal plane (Fig. 3, on page 329). Here, again, a simple method of assembling the compressor stator blades has been adopted. The blades, of stainless steel, are brazed on to stainless-steel half-rings, and the latter are inserted in dovetail grooves in the half-castings; they are located against rotation by an occasional locking screw which passes right through the casing and is retained by a nut on the outside. The combustion-chamber outer and inner casings, which carry respectively the two main trunnion mountings and, as already noted, the centre and rear main bearings, form a welded assembly of 16-s.w.g. mild steel; the two flame tubes, which comprise spot-welded assemblies of Nimonic 75 sheet, are free to float longitudinally, each being located by three dowels on the turbine stator ring, which is bolted to the rear end of the combustion-chamber casing. Figs. 5 and 6, on page 336, illustrate the combustion-chamber. The turbine stator ring, machined from a high-nickel alloy heat-resisting steel, Rex 448, is the only component employing an expensive material.

The turbine stator assembly is also of unusual construction. The 93 stator blades, of Crown Max rolled strip, are freely supported in aerofoil slots punched in two locating rings of Nimonic 75 sheet. Thus, the blades are completely free to expand and contract; they are located radially by the diaphragm on the inside, and by the turbine stator ring on the outside. Aft on the turbine stator ring is the exhaust cone, a Nimonic 75 welded sheet assembly, the main member of which is attached to the outer tube by three streamline struts.

Fuel, Oil and Starting Systems.

The fuel-system components, supplied by Joseph Lucas (Gas Turbine Equipment), Limited, Birmingham, comprise the pumps unit and the control unit. Integral with the gear pump is the over-speed governor, which is of the simple bob-weight type, an unusual feature in British aircraft gas turbines, in which hydraulic governors are usually employed. The fuel pump supplies fuel at 450 lb. per square inch to the control unit, which incorporates a barometric pressure control unit responding to changes in forward speed and altitude and controlling the flow of fuel entering the control unit through a servo-operated spill valve. An electrically-actuated throttle is also built on to the control unit, which also serves as a fuel shut-off valve. Since, however, the electric actuator does not act instantaneously, a solenoid-operated emergency shut-off valve is also provided. Also within the control unit is a starting solenoid valve, which directs fuel to the priming line for starting, and a pressure-increasing valve which operates only for starting and ensuring that an adequate fuel pressure is built up in the priming line.

From the fuel control unit, two fuel pipelines pass, respectively, to a manifold ring and a priming ring which encircle the engine at the forward end of the combustion chamber. From the main fuel manifold ring, 12 equally-spaced feeds are led to pads in the combustion-chamber casing, each of which supplies two vapourising tubes. The priming ring, which serves for starting the engine, feeds eight high-pressure primer jets. Ordinary high-tension sparking plugs are adjacent to two of the primer jets.

For starting, a compressed-air supply at 120 lb. per square inch is connected through a non-return valve to two ¼-in. diameter pipes, which direct air on to the turbine blades. The normal starting procedure is to run up the turbine to about 1,000 r.p.m. before operating the starter button, which energises the sparking plugs and the starting solenoid valves; the compressed-air supply is not disconnected until the turbine speed has attained about 3,000 r.p.m. The starter button is released as soon as ignition has taken place, usually after about 3 seconds.

The oil system comprises a Pilgrim Way double-acting two-piston pump with four deliveries of ½ pint per hour each. Three of these, as already mentioned, are taken to the main rotor bearings. The fourth is fed to the auxiliary gearbox. There is no oil-return system, oil from the centre and rear bearings passing out with the cooling air into the jet stream in the form of an oil mist. Oil from the front bearing and the gearbox is spilled overboard through one of the air-intake casing struts.

"Long-Life" Viper.

The engine under development for the Percival Jet Provost will be basically similar to the ASV3, but the flame tubes will be of more robust construction, and will have ¼-in. corrugations, each corrugation being spot-welded to the adjacent section. The first-stage compressor-rotor blades will be of steel instead of aluminium alloy. The front rotor bearing will be provided with a return oil feed. Since provision must be made for relighting in the air on the piloted aircraft, high-energy ignition plugs will replace the sparking plugs, and a modified fuel system, with a Lucas piston pump and an acceleration control to prevent stalling on rapid throttle opening, will be fitted.

Probe and Amplifier for Transients.—A hand probe and a delay amplifier have been developed by E.M.I. Factories, Ltd., Hayes, Middlesex, for examining the leading edge of a short-duration waveform, or for transients. They are designed primarily for use with the E.M.I. Monitor type 3794, but can be used with any high-speed oscilloscope. It is claimed that a jitter-free signal can be presented under very adverse conditions. The body of the probe is 1¾ in. in diameter and 7¼ in. long. In it are a screened cathode-follower unit and an interchangeable attenuator unit. Seven attenuators, either resistive or capacitive, are made. The overall signal delay in the amplifier is 0·5 micro-seconds, and the transient response 0·07 micro-second time of rise.

AIRCRAFT INDUSTRY'S DISPLAY AT FARNBOROUGH.

Fig. 1. "Princess" Flying-Boat at High Altitude.

THE AIRCRAFT INDUSTRY'S DISPLAY AT FARNBOROUGH.

During this week the annual flying display of the Society of British Aircraft Constructors has been taking place at Farnborough, Hampshire. As was to be expected, the profusion of new types of military and civil aircraft that have appeared year by year since the second World War, as a result of the rapid development of the aircraft gas-turbine, is less evident now that production programmes have become stabilised and the pattern of the immediate future of military aviation and civil transport operations has become apparent. With a few exceptions, therefore, most of the aircraft on view are developments of machines that have already been seen in public.

When the Vickers-Armstrongs Viscount and de Havilland Comet airliners first appeared at Farnborough, they aroused great hopes that British commercial aircraft might once again take their place in the world's markets. These hopes are now being realised; Viscount airliners (represented this year at Farnborough by a standard production Viscount 700) are in profitable service with British European Airways, and have been ordered by operators in France, Ireland, Iraq, Australia, Canada, and India. A total of 86 Viscount aircraft is at present on order.

"Comet" Airliner.

Comet Series 1 and 1A airliners, powered by four 5,000-lb. thrust de Havilland Ghost engines, are in service with British Overseas Airways Corporation, Union Aeromaritime de Transport, Air France, and the Royal Canadian Air Force; they have completed a total of over 5,000,000 miles of satisfactory operation with remarkably few teething troubles.

At the time of going to press, it was expected that the first production version of the Comet Series 2 airliner, which made its first test flight on August 27, would appear on one or two days during the week of the display. This aircraft, designed and constructed by the de Havilland Aircraft Company, Limited, Hatfield, Hertfordshire, is illustrated in Fig. 2. The Comet Series 2 airliner is powered by four Rolls-Royce Avon engines, each developing 6,500 lb. thrust. With a fuselage 3 ft. longer than that of the 36-seat Series 1 Comet at present in service with the British Overseas Airways Corporation, it can carry 44 passengers economically over stage lengths ranging from 1,750 miles to 2,200 miles. The fuel capacity is increased over that of the Comet Series 1 by 1,000 gallons, to 7,000 gallons. The maximum all-up weight of

AIRCRAFT INDUSTRY'S DISPLAY AT FARNBOROUGH.

FIG. 2. PRODUCTION "COMET" SERIES 2 AIRLINER.

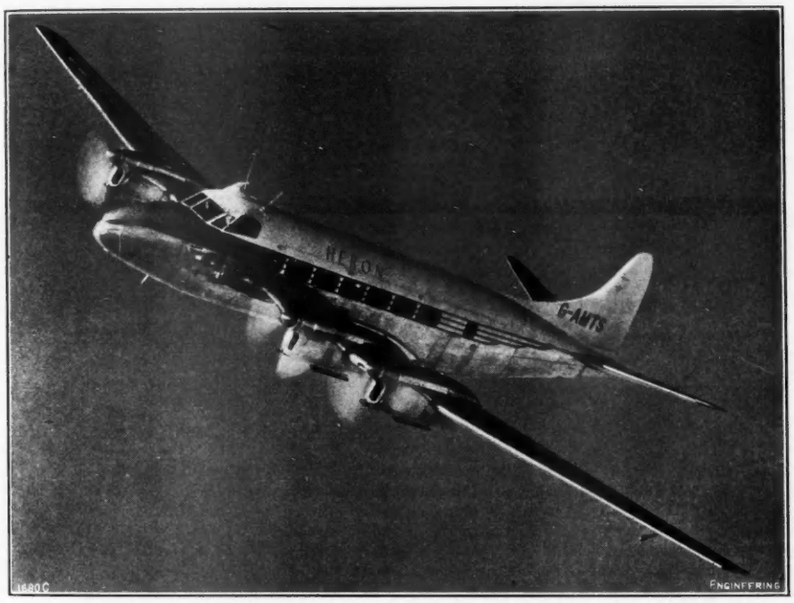


FIG. 3. "HERON" SERIES 2 AIRLINER.

the Comet Series 2 is 120,000 lb., and the maximum capacity payload is 13,500 lb. A total of 28 Series 2 Comets, for the British Overseas Airways Corporation and operators in Australia, Japan, Venezuela, Brazil and France, have been ordered.

The Series 3 Comet, the prototype of which is expected to fly next year, is a larger machine with greater economic potentialities. It provides accommodation for 58 first-class or 76 tourist passengers, and is intended for operation over stage lengths up to 2,500 miles; it will be powered by four 9,000-lb. thrust Rolls-Royce Avon RA.16 engines. Three Comet 3 airliners have been ordered by Pan American World Airways (with an option for a further seven), and two by Air India; British Overseas Airways Corporation have an option for ten and Panair do Brasil for two.

"BRITANNIA" AIRLINER.

The Britannia propeller-turbine airliner is still under development by its manufacturers, the Bristol Aeroplane Company, Limited, Filton, Bristol, but 25 passenger machines have been ordered by British Overseas Airways Corporation, and they intend to purchase five Britannia freighters, pending Government approval; Qantas Empire Airways are also intending to purchase six Britannias. The Britannia flying at Farnborough has now been fitted with Proteus 3 propeller-turbine engines of the type which will power the production machines; last year the prototype was flown with the less powerful Proteus 2 engines.

The all-up weight of the Britannia is 140,000 lb. The aircraft destined for British Overseas Airways Corporation will, initially, offer accommodation for 63 first-class, or 90-93 tourist passengers. With full payload, 25,000 lb., the Britannia can operate over a stage distance of 3,150 miles; and, with full fuel tanks, it can carry 50 passengers and baggage direct between London and New York, a route on which severe headwinds are prevalent, with 80 per cent. regularity. The cruising speed is 360 m.p.h.

"HERON" SERIES 2 AIRLINER.

The Series 2 Heron short-range airliner, illustrated in Fig. 3, with a retractable undercarriage, is displayed for the first time by the de Havilland Aircraft Company. The version demonstrated is furnished as an eight-seat machine for executive use, and is also available as a 14-seat or 17-seat passenger-transport aircraft. The retractable undercarriage results in greater economy over long-stage distances, in comparison with the fixed-undercarriage Series 1 Heron aeroplane, which appeared for the first time in 1950 and was described on page 239 of our 170th volume (September 22, 1950). It is powered by four Gipsy Queen 30 Mark 2 engines each developing 250 h.p. at sea level. The flaps, undercarriage, and wheel brakes are pneumatically operated. The aircraft has a span of 71 ft. 6 in. and an overall length of 48 ft. 6 in. At an all-up weight of 13,000 lb. it will take off and clear a 50-ft. obstacle in 750 yards; the rate of climb at sea level is 1,140 ft. per minute. The Heron 2 has a cruising speed of 183 miles per hour at 8,000 ft., and will carry 14 passengers and luggage over a stage length of 690 miles. Landing over a 50-ft. obstacle it requires a distance of 665 yards.

"PRINCESS" FLYING-BOAT.

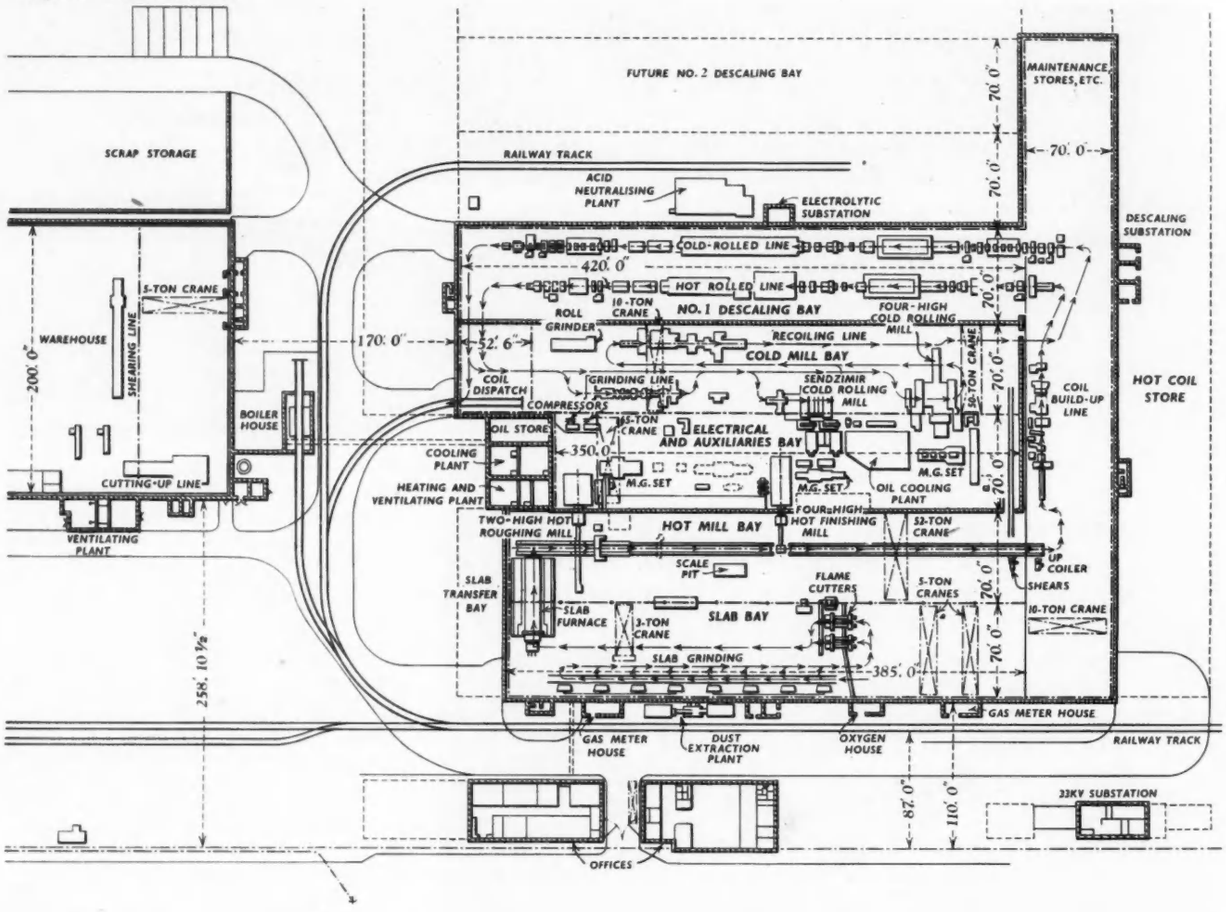
Although the 140-ton Princess flying-boat appeared over Farnborough last year, on one day, it was not present on the public days, and for many people this week will have offered their first opportunity of seeing this beautiful aircraft. A comprehensive description of the Princess, which is designed and constructed by Saunders-Roe, Limited, East Cowes, Isle of Wight, was given in ENGINEERING on pages 289, 371, 429, 495, and 591 of our 174th volume (1952). Since then, the Princess has completed ground resonance tests and most of the preliminary performance and handling tests required before the Certificate of Airworthiness trials can be undertaken. The control and stability characteristics of the Princess have proved to be excellent, and the operation of the powered flying controls is entirely satisfactory. Although the ten Proteus 2 engines installed at present are delivering only 80 per cent. of the power for which the aircraft was designed, it has been found possible to take off at a weight of 320,000 lb.—about 5,000 greater than the original designed all-up weight. Recently, the Princess has been carrying out high-altitude tests, although the air-conditioning system is still incomplete and the crew have had to wear oxygen masks. Fig. 1, on the opposite page, shows the Princess during one of these flights.

(To be continued.)

MERCURY DISCHARGE LAMP WITHOUT COLOUR DISTORTION.—The British Thomson-Houston Co., Ltd., Aldwych, London, W.C.2, have produced a high-pressure mercury discharge lamp which gives a light free from colour distortion. This important improvement has been obtained by coating the inside of the bulb with a new type of phosphor. When subjected to ultra-violet radiation this coating emits red light, which blends with the blue-green radiation from the mercury vapour to produce an approximately white light. The new phosphorus also allows a smaller bulb to be used for both the 80-watt and 125-watt lamps.

THE SHEPCOTE-LANE PLANT OF FIRTH-VICKERS STAINLESS STEELS, LTD.

Fig. 1. LAYOUT OF MILLS.



(1605 A.) "ENGINEERING."

THE SHEPCOTE-LANE PLANT OF FIRTH-VICKERS STAINLESS STEELS, LTD.

It was the declared desire and intention of the Iron and Steel Corporation, when they became the *de facto* owners of the British steel-producing industry, that the individual firms who had been nationalised should retain their individuality, their titles and, it was hoped, their goodwill in British and foreign markets. It was reasonable to assume, therefore, that they would be allowed to retain also the credit due to them for the many plant improvements and developments which were initiated while the industry was still in private ownership. Some of those developments, including both the re-equipment of existing steelworks and the construction of extensions, have been the subject of articles in ENGINEERING; and to these we are now able to add some description of a plant of more than usual interest in that it is entirely new, having been constructed on a site which was previously open agricultural land. This is the stainless-steel mill of Messrs. Firth-Vickers Stainless Steels, Limited, at Shepcote-lane, Sheffield, which has been designed to produce, as a first stage in an ultimately bigger scheme, some 20,000 tons a year of stainless-steel sheets, up to a metre in width, from cold-rolled, softened and descaled strip, rolled in the works from the slabs.

The total area of the land that has been acquired is about 70 acres, though not all of this is included in the section of the works now to be described. The scheme was the joint production of the Firth-Vickers firm and of Messrs. Samuel Fox and Company, Limited, and consists, in the first place, of two hot reversing mills, one for the initial reduction and the other for rolling the strip to the finished (hot) thickness; and two cold-rolling mills which reduce the strip from 0·80 in. thick to any desired gauge without intermediate softening. The layout of the buildings and plant is shown in Fig. 1, herewith, from which the sequence of operations can be followed; and general views of the mill and of the office buildings are reproduced in Figs. 2 and 3, opposite.

The slabs as delivered to the plant are 20 in. wide, about 4½ in. thick, and in length up to 42 in., and weigh 1,070 lb. They enter the shop by rail and are then stacked in the slab storage bay. Thence they are transferred as required to the slab furnace, and so to the two-high roughing mill. On leaving this mill, the hot strip travels on a roller conveyor to the four-high finishing mill, beyond which is a hot-coil store. Here they can be either retained in stock or, if a long run is in progress, passed straight to the coil build-up line, where they are flash butt-welded into a continuous strip for feeding to the descaling bath. In the build-up line, the separate coils are first built up into larger coils, weighing from 3 to 5 tons each, and have both edges trimmed. Service strips for handling are also welded on to each end.

In the descaling bay, a coil passes first through an uncoiler, on to a roller flattening machine and thence to a welding machine, which attaches it to the end of the preceding coil. Beyond the welder, the strip thus formed is looped upwards so that sufficient length is "stored" to enable it to maintain a uniform speed through the softening furnace while the next weld is being made. On leaving the furnace, the strip is cooled by an air blast and fed into the sodium-hydride descaling tank. A water quench is the next operation, after which the strip passes through an acid bath, is washed with hot water and dried by hot air, and passed through another storage loop to enable the welded joints to be cut out. The cut lengths are then recoiled and transferred to the cold-rolling mill. It should be mentioned that the sodium-hydride descaling bath is for hot-rolled strip; cold-rolled strip passes through the acid bath only. The separate lines for hot-rolled and cold-rolled strip are indicated in Fig. 1.

If, by this time, the strip has been reduced to its final thickness, it is coiled (with a layer of paper between the coils) and taken to the coil dispatch store; but if it is required to be further reduced in thickness it is returned to the cold-rolling mill to be rolled down, after which it is again softened and descaled. The service strips which are cut out of the continuous strip after descaling are returned to the build-up line for re-use.

The foregoing description having briefly outlined the sequence of operations, some further details may be given of the component parts of the plant. The buildings, which cover about 12 acres, comprise five bays, each 70 ft. wide, with saw-tooth roofs, glazed on the vertical sides; and an administrative block which forms the frontage on to Shepcote-lane. The slab bay and the hot-mill bay are 385 ft. long; the electrical and auxiliaries bay is 350 ft. long; and the cold-mill bay and the descaling bay are each 420 ft. long. Extending from the end of the mill bays, as shown in Fig. 1, is a large maintenance bay. The warehouse for storing the finished strip is to the left of the buildings in Fig. 1, but is not shown. The scheme for the development of

SHEPCOTE-LANE STAINLESS-STEEL MILL.

FIG. 2. GENERAL VIEW OF SHEPCOTE-LANE PLANT.

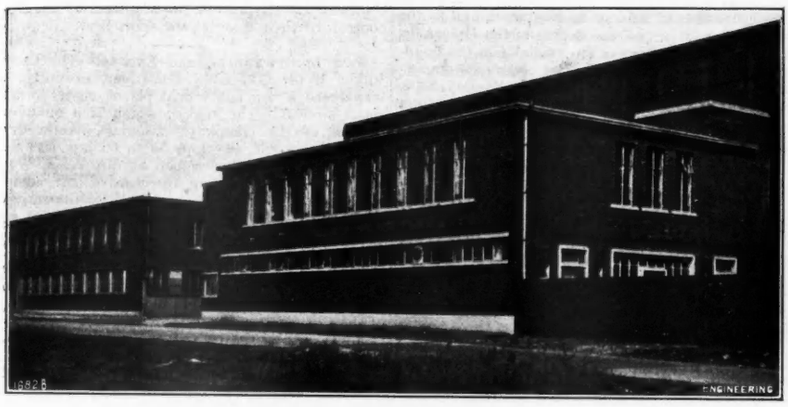


FIG. 3. OFFICE BLOCK.

FIG. 4. ROUGHING MILL AND HOT MILL LINE.

the site was formulated soon after the end of the war, but it was not until April, 1948, that work on it actually began. From the date when the ground was broken, the construction of the present plant has taken about five years. The contractors for the main mill buildings were Sir William Arrol and Company, Limited, of Glasgow.

The contractors for the hot mills and their equipment were the Davy and United Engineering Company, Limited, Sheffield, the electric motors and their control gear being provided by the British Thomson-Houston Company, Limited, Rugby. The first of the two cold mills, with its coilers, was supplied by W. H. A. Robertson and Company, Limited, of Bedford, and the motors, etc., by the Metropolitan-Vickers Electrical Company, Limited, Manchester. The second cold mill, of the Sendzimir "cluster" type, was constructed by the Waterbury Farrel Foundry and Machine Company, of Waterbury, Connecticut, U.S.A., and is driven by an electric motor supplied by the English Electric Company, Limited. The slab-heating furnace, which is gas-fired, was supplied by Priest Furnaces, Limited; the coiling, softening and descaling lines by the Wellman Smith Owen Engineering Corporation, Limited, London; the butt-welding machines by A.I. Electric Welding Machines, Limited, Inverness; and the variable-speed drives—necessary to match the speed of the strip through the mills, etc., with its constantly-varying cross-section and length—by Vickers-Armstrongs Limited, Elswick, Newcastle-on-Tyne.

It may be added that the hot mill has been designed to roll slabs weighing up to 6,000 lb. each, which would enable lengths up to 350 ft. to be rolled instead of the 60-ft. lengths obtained at present; and the roughing mill can be used also to produce stainless-steel plates from $\frac{3}{16}$ in. to $\frac{1}{2}$ in. thick and up to 63 in. wide by 21 ft. long.

The stainless-steel slabs which are the raw material of the plant are in rough form and, as received, are of varying lengths. They are first dressed by grinding in four booths and are then conveyed to flame-cutting machines, which cut them into portions of the sizes previously mentioned, weighing about 1,070 lb. each. The slabs then pass into the heating furnace, which is of the pusher type, measuring 53 ft. in length and 12 ft. wide, and is arranged at right angles to the roughing-mill line. The twin hydraulic pushers can be used either independently, to push two rows of small slabs, or together, to push a single row of larger slabs. The slabs are placed on the furnace-charging platform by a crane running on a floor track. The heated slabs are discharged from the furnace down a cast-steel chute to the roller table at the intake end of the roughing mill, on which they are arrested by a spring-loaded bumper. The approach table of the mill is also provided with a reverse take-off for the purpose of dealing with slabs when it is desired to empty the furnace without passing the slabs through the mill.

The hot line comprises two mills, as previously stated, namely, the 35-in. by 72-in. two-high reversing roughing mill, with a vertical edging mill, which reduces the slabs to a thickness of about $1\frac{1}{4}$ in.; and a fast 27-in. and 53-in. by 48-in. four-high reversing finishing mill, which brings the strip down to its finished thickness in one heat. The roughing mill is designed to be capable of rolling stainless-steel plates from slabs weighing up to a ton; it was for this reason that the width was made 72 in. and the roll diameter 35 in. Turning buttons are provided on the tables, on both the ingoing and outgoing sides of the mill, for broadsiding. Slab pushers of the overhead type ensure a positive entry of the slabs between the rolls; these are in addition to the hydraulic self-centring rack-type pushers on the ingoing table itself. The four-roll feed table is driven by a separate electric motor coupled to a double-reduction gear.

The roughing mill is driven by a motor of 2,800 h.p., running at 30 to 60 r.p.m., corresponding to rolling speeds of 275 ft. to 550 ft. per minute, the drive being transmitted through universal-coupling spindles. The totally-enclosed pinion stand contains double-helical pinions of 36 in. pitch-circle diameter, driving through flexible couplings of the internal-gear type. The top roll is hydraulically balanced.

(To be continued.)

DRAUGHT-PROOF WINDOW FAN.—The General Electric Co., Ltd., Kingsway, London, W.C.2, have introduced a window fan, manufactured by Messrs. Woods of Colchester, Ltd., which incorporates an iris shutter, so that the draught is completely excluded when the unit is at rest. This shutter is operated by two nylon cords, one of which opens it and starts the driving motor, while the other closes the aperture and switches the motor off. When open, the shutter disappears into a narrow recess in the plastic casing, so that it does not rattle or collect dust. The fan portion can be quickly removed for cleaning without disturbing the part fixed to the window. The fan is made in two sizes with extraction capacities of 15,000 and 30,000 cub. ft. per hour respectively, and the rate of extraction can be varied by a remote-control regulator which gives four motor speeds.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

CLYDE NAVIGATION TRUST.—Revenue and expenditure of the Clyde Navigation Trust, for the year ended June 30 last, created records, the former being 1,898,934*l.* and the latter, 1,797,412*l.* The heavy expenditure was attributed to abnormal repairs, the reconstruction of the south wall at Rothesay Dock, dredging, and increased costs of wages and materials. The trustees announced at their annual meeting, held in Glasgow on September 1, that they had accepted the tender of Holland & Hannan and Cubitts (Scotland), Ltd., Edinburgh, of 573,882*l.* for the extension eastwards of Shieldhall riverside quay. It was stated by Sir Patrick Dollan, convener of the Committee on New Works and Maintenance of Harbour and River, that the tender was the lowest, and the difference between the lowest and highest was nearly 200,000*l.*

SHIPBUILDING ACTIVITY.—Scottish shipbuilders are so far maintaining their launching figures at a higher level than those of last year. In the Clyde area the tonnage entering the water in the eight months to the end of August aggregated 243,495, against 245,613 tons in the corresponding period of 1952, but the East of Scotland figures were higher at 55,586 tons, compared with 46,772 tons.

ROAD ALONG LOCH LOMOND.—Proposals for an improved trunk road along the banks of Loch Lomond, from Balloch to Ardlui, have been approved by the Ministry of Transport, and details of the scheme are now being studied by the Ministry in conjunction with Dumbarton County Council. The scheme will then be submitted to the Ministry for final approval, to allow work to be commenced. The plans, drawn up originally in 1936-37, involve "certain diversions" to the existing road, the larger part of which would be retained in use. They are understood to include the construction of a new high-level road which, in conjunction with the existing road, would allow a two-way route—one for all north-going traffic and the other for all south-going traffic.

WITHDRAWAL OF GOODS-TRAIN SERVICES.—On and after September 21, the goods-train service between Tillietudlem and Brocketsbrae, Lanarkshire, will be withdrawn. Tillietudlem will be converted into a public siding to deal with traffic in full truck-loads (other than fruit). The freight service between High Blantyre and Strathaven (North) will also be withdrawn, but alternative rail facilities will be available at Hamilton, Meikle Earnock, Quarter, and Strathaven (Central).

CLEVELAND AND THE NORTHERN COUNTIES.

AUSTRIAN STEEL PLATES ON NORTH-EAST COAST.—A consignment of steel plates from Austria has arrived in the River Wear in the m.s. Sylvian Coast. The shipment is part of an order for steel plates placed by the Government some time ago to relieve the shortage in Britain.

SEPTEMBER LAUNCHES ON THE TYNE.—Tyne shipyards are to launch four ships and a pontoon this month, bringing the river's output for the first nine months of the year to 21 vessels, aggregating nearly 177,000 gross tons, compared with 18 vessels, totalling 135,012 gross tons, in the corresponding period last year. September's launches will include the cargo ship Hazelmoor from the Hebburn yard of R. and W. Hawthorn, Leslie & Co., Ltd., built for the Moor Line; the 5,750-ton vessel Neptune, built by Swan, Hunter, and Wigham Richardson, Ltd., for Panama owners; a 5,950-ton cargo ship constructed by John Readhead and Sons, Ltd., South Shields, for Hogarth & Sons, Glasgow; and a small tanker for the Anglo-Saxon Petroleum Co.

FACTORY EXTENSIONS ON TEES-SIDE.—At a meeting of the Tees-side Advisory Committee of the Northern Regional Board for Industry it was reported that, during the three months May, June and July, factory extensions covering 151,336 sq. ft. were sanctioned on Tees-side. These are expected to result in employment for an additional number of 52 men and 215 women. Since the end of the war, 7½ million square feet of factory space have been completed on Tees-side and, in addition, another 4½ million square feet are under construction. Of the area completed to date, over 2½ million square feet are for the chemical and associated trades.

METHANE FROM COLLIERIES FOR HOUSEHOLD USE.—Methane gas recovered from the Haig Pit, Whitehaven, is now being used by gas consumers in the Whitehaven area. The gas is being pumped from the workings at the colliery to the Whitehaven gasworks of the Northern Gas Board. It has been pointed out by Mr. J. Bowman, chairman of the Northern (Northumberland and Cumberland) Division of the National Coal Board, and Mr. E. Crowther, chairman of the Northern Gas Board, that the primary reason for using the methane in this way is to improve working conditions in the pit; commercial considerations were secondary. By using methane for firing the colliery boilers, about 5,000*l.* worth of coal is being saved each month.

WEST HARTLEPOOL TECHNICAL COLLEGE.—The prospectus of the West Hartlepool Technical College for the session 1953-54 has now been issued. In the engineering department, part-time day, combined part-time day and evening, and also evening courses are available for apprentice marine, mechanical and electrical engineers. These lead to Ordinary and Higher National Certificates in mechanical or electrical engineering, to the associate-membership examination of the Institution of Mechanical Engineers, and to the external intermediate science degree of the University of London. Similar courses are available in the building, pure and applied science, and commerce departments. Part-time classes commence on Monday, September 21. Copies of the prospectus are available from the Principal, the Technical College, West Hartlepool.

LANCASHIRE AND SOUTH YORKSHIRE.

COLLIERY REORGANISATION.—A large reorganisation scheme at Maltby Main Colliery, South Yorkshire, has been inaugurated to increase production from 20,000 to 30,000 tons of coal a week. The main object of the underground planning is to bring locomotive haulage into full use by deepening the shafts and driving level roadways out to the three major producing districts, which have reserves rich enough to keep the pit going for many years. Three main loading points, with Diesel locomotives and three-ton capacity mine cars, will replace tubs and rope haulage.

FURTHER RESTRICTIONS ON IMPORTED CUTLERY.—The ban imposed by Norway, in February, on the import of white-handled knives diverted buying to other types of cutlery. Norway has now responded by doubling the customs tariff on imported knives and forks having handles of fibre, wood, iron, celluloid or other materials. Sheffield cutlery manufacturers state that this will seriously hamper business. Norway was a good market for Sheffield cutlery until 1947, when an import quota of 10,000*l.* worth of imported cutlery a year was imposed.

THE LATE MR. J. H. GOURLEY.—Mr. John Henry Gourley, chairman and managing director of Wombwell Foundry & Engineering Co., Ltd., died on September 1 at his home, The Towers, Brincliffe-crescent, Sheffield, at the age of 76. He founded the firm before the war of 1914-18. His apprenticeship as an engineer was served with William Jessop & Sons, Ltd., Sheffield.

THE MIDLANDS.

PRODUCTION ENGINEERS' CONVENTION.—The second national convention organised by the Institution of Production Engineers for the Graduates and Students of the Institution was held in Birmingham University on September 5, the chair being taken by Professor T. U. Matthew, who occupies the Lucas chair of the principles of engineering production at the University. Papers were presented on "Economic Factors in Engineering Production," by Mr. Ian T. Morrow, deputy managing director of the Brush Group; on "Human Factors in Engineering Production," by Mr. J. Munro Fraser, M.A., of Birmingham College of Technology; and a "Review and Outlook for the Future," by Mr. Walter C. Puckey, the President of the Institution. The concluding summary of the proceedings was made by Sir Cecil M. Weir, K.C.M.G. During the day, visits were paid to the University's engineering-production laboratories, and there was also a display of films.

DUST CONTROL IN COAL SEAMS.—Experiments are being carried out by the National Coal Board, West Midlands Division, with water infusion to control the dust in coal seams. Water is forced at high pressure behind the coal face, with the object of reducing the amount of dust liberated when the coal is brought down. The experiments are being conducted at four pits in the Cannock Chase coalfield, namely, those at Hilton Main, Walsall Wood, Wimblebury, and Cannock Wood. The work being done is part of a long-term attempt which the Board are undertaking to prevent pneumoconiosis.

DAMAGED RAILWAY HALT TO CLOSE.—Jackfield Halt, on the Severn Valley line of British Railways, Western Region, is to be closed to passenger traffic as a result of damage caused by the local landslip. The land movement has necessitated constant attention to the track, and the platforms of the halt have been so affected that it is no longer possible, in the interests of public safety, to keep it in use. A suggestion that the halt should be moved to a new site clear of the landslip, which is relatively small in extent, has been rejected on the ground that the small number of passengers carried to Jackfield would not warrant the expense. Only passenger services will be affected; freight trains will continue to run as usual.

WORKS TRAFFIC CONTROL BY RADIO.—Jaguar Cars, Ltd., Holbrook-lane, Coventry, are installing short-wave radio-telephone sets to control their internal works transport. Eleven radio sets, each costing 85*l.*, are being fitted to fork-lift trucks and electric pallet trucks, to place the drivers in constant communication with the transport manager's office. The company are the first in the Midlands to adopt radio control for their internal transport fleet.

NEW LIGHTWEIGHT AERO ENGINE.—The Coventry Victor Motor Co., Ltd., Cox-street, Coventry, have introduced a new lightweight petrol engine for use in small aircraft. The engine, which is a modification of one of the company's standard overhead-valve industrial models, develops 55 to 60 h.p. and weighs 250 lb. It has been designed by Mr. W. A. Weaver, chairman and managing director of the company, whose aircraft experience goes back to the early days of flying. The engine is now in production at a rate of 200 a month.

TRAINING IN THE CHEMICAL INDUSTRY.—The scheme for training in the chemical industry, which is being put into operation in the autumn under the auspices of the Chemical and Allied Industries Joint Industrial Council, will be the responsibility in the Midlands of the regional committee of the Council, under the chairmanship of Mr. G. M. Hopps, of Bakelite, Ltd., Tyseley, Birmingham. The secretary is Miss M. G. McKenzie, of British Industrial Plastics, Ltd., Oldbury. A five-years apprentice-hip is being introduced, and theoretical training will be given at the Chance Technical College at Smethwick.

SOUTH-WEST ENGLAND AND SOUTH WALES.

DEFENCE PROGRAMME ORDERS IN WALES.—Reporting to the Welsh Board for Industry, the Ministry of Supply has stated that, during the 12 months ended June 30 last, 1,750 contracts under the defence programme, valued at 10,800,000*l.*, had been placed with private firms in Wales. In addition, 1,700 orders, valued at 10,100,000*l.*, were placed during the period with the Royal Ordnance and Ministry of Supply agency factories in Wales. Since the programme began in August, 1950, about 350 firms in Wales have participated in Government work under direct contracts amounting to 37,500,000*l.*, while, in the same period, orders valued at 26,000,000*l.* have been placed with Royal Ordnance and Ministry of Supply agency factories.

RHONDDA-VALLEY PITHEAD BATHS.—Two new pithead baths were opened in the Rhondda Valley last week. One at Glenrhondda Colliery cost 31,000*l.*, and the other, at Gelli Colliery, cost 56,000*l.* That at Gelli will provide for 840 men. Mr. H. Lyn Jones, deputy manager of the South-Western Division of the National Coal Board, speaking at the opening of the Gelli baths, said that when the Board took over the industry, four collieries in the present No. 3 Area were provided with baths. With the opening of the Gelli baths, seven collieries were so provided, four more baths were in course of construction, and three were in the planning stage.

CLOSURE OF BRIDGEND FURNITURE FACTORIES.—A.V.P. Industries Ltd. have announced their intention of closing three furniture factories in Bridgend to concentrate production in the London area. A fourth associated company which transferred its premises from Bridgend to Cardiff some time ago is not affected. The three factories were established on the Bridgend Trading Estate about six years ago and, until the furniture-trade slump some two years ago, employed about 180 persons. Recently, however, the number employed has been fewer than 100.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Monday morning in the week preceding the date of the meeting.

ROYAL AERONAUTICAL SOCIETY.—Monday, September 14, 6 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, Westminster, S.W.1. Forty-First Wilbur Wright Memorial Lecture on "Structures," by Professor N. J. Hoff.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—*Central London Branch:* Monday, September 14, 7 p.m., St. Ermin's Hotel, Caxton-street, Westminster, S.W.1. "Electric Tools," by Mr. N. T. Tharme. *Manchester Branch:* Wednesday, September 16, 7.30 p.m., Engineers' Club, Albert-square, Manchester. "Electronics in Industry," by Mr. A. Williams. *Portsmouth Branch:* Thursday, September 17, 7.15 p.m., "The Air Balloon," Portsmouth. "Association Affairs," by Mr. E. A. Bromfield. *Kent Branch:* Thursday, September 17, 8 p.m., County Hotel, Canterbury. "V-Belt Drives," by Mr. J. H. Cleator.

INSTITUTION OF PRODUCTION ENGINEERS.—*Coventry Graduate Section:* Tuesday, September 15, 7.30 p.m., The Hare and Squirrel Hotel, Coventry. Discussion on "Aspects of Production Engineering." *Birmingham Section:* Wednesday, September 16, 7 p.m., James Watt Memorial Institute, Birmingham. "The Ethics of Production," by Mr. R. W. Mann. *Derby Section:* Monday, September 21, 7 p.m., Midland Hotel, Derby. Presidential Address, by Mr. W. C. Puckey. *Manchester Graduate Section:* Tuesday, September 22, 7.15 p.m., Reynolds Hall, College of Technology, Manchester, 1. "Diecasting," by Mr. T. Bradshaw. *Shrewsbury Section:* Wednesday, September 30, 7.30 p.m., Shrewsbury Technical College, "The Engineer's Part in the Production of Pottery" (with film), by Mr. J. Robinson.

COMBUSTION ENGINEERING ASSOCIATION.—*Northern Section:* Wednesday, September 16, 2.15 p.m., Queen's Hotel, Leeds. Informal Discussion on "Advantages and Disadvantages of a Delivered Price Scheme for Industrial Coals," introduced by Mr. R. J. Moffat.

INCORPORATED PLANT ENGINEERS.—*Glasgow Branch:* Wednesday, September 16, 7 p.m., Scottish Building Centre, 425-427, Sauchiehall-street, Glasgow, C.2. "Education and the Plant Engineer," by Mr. H. N. Henry. *Merseyside and North Wales Branch:* Monday, September 21, 7.15 p.m., Radiant House, Bold-street, Liverpool. "Paint in Industry," by Mr. P. I. Gay. *Sheffield and District Branch:* Thursday, September 24, 7.30 p.m., Grand Hotel, Sheffield. Discussion on "Electrical Factory Regulations." *Yorkshire Branch:* Monday, September 28, 7.30 p.m., The University, Leeds. "Prestressed Concrete," by Dr. R. H. Evans.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*North-West Centre:* Wednesday, September 16, 7.30 p.m., The Victoria Hotel, Wigan. "The Use and Abuse of Fuels," by Mr. W. E. P. Johnson. *Yorkshire Centre:* Thursday, September 17, 7.30 p.m., Hotel Metropole, King-street, Leeds, 1. "Vehicle Maintenance from the Aspect of Safety," by Mr. A. H. Dack. *North-East England Group:* Tuesday, September 22, 7 p.m., Royal County Hotel, Durham City. "The Maintenance of High-Speed Diesel Engines," by Mr. H. L. Parrish.

INSTITUTE OF WELDING.—*North London Branch:* Thursday, September 17, 7.30 p.m., The Polytechnic, Regent-street, W.1. "Developments in Welded Pressure Vessel Manufacture," by Dr. H. Harris.

INSTITUTE OF MARINE ENGINEERS.—Tuesday, September 22, 5.30 p.m., 85, The Minories, E.C.3. Presidential Address by Sir Gilmour Jenkins.

INSTITUTION OF LOCOMOTIVE ENGINEERS.—Wednesday, September 23, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, Westminster, S.W.1. Presidential Address, by Mr. R. C. Bond.

ROYAL SANITARY INSTITUTE.—*Grimsby Sessional Meeting:* Thursday, September 24, 11.30 a.m., Town Hall, Grimsby. Joint meeting with the *East Midland District* of the INSTITUTION OF MUNICIPAL ENGINEERS. (i) "Grimsby Main Drainage: Combined Sewage and Surface-Water Pumping Stations," by Mr. S. W. Norman and (ii) "A Modern Abattoir," by Mr. Harold Parkinson.

INSTITUTION OF MECHANICAL ENGINEERS.—*North-Western Branch:* Thursday, September 24, 6.45 p.m., Engineers' Club, Albert-square, Manchester. "Design of Precision-Grinding Machines," by Mr. C. H. Asbridge. *Western and Southern Branches:* Friday, September 25, 6.30 p.m., South Dorset Technical College, Weymouth. Joint Meeting. "The Electricity Supply Industry," by Mr. E. A. Logan. *Southern Branch:* Wednesday, September 30, 7 p.m., Brighton Technical College. "The Railways and Coal," by Mr. R. G. Jarvis.

TELEVISION SOCIETY.—Thursday, September 24, 7 p.m., Cinematograph Exhibitors' Association, 164, Shaftesbury-avenue, W.C.2. "Transistors and Other Crystal Valves," by Mr. D. D. Jones.

CONTRACTS.

MARCONI'S WIRELESS TELEGRAPH CO., LTD., Chelmsford, Essex, have obtained an order from the Swiss broadcasting authorities for a complete television outside-broadcasting vehicle to be delivered within nine months. The vehicle will contain three camera channels for three of the firm's image orthicon cameras with their controls, mixers and sound-mixing equipment.

LEYLAND MOTORS LTD., Leyland, Lancashire, have obtained an order valued at 200,000*l*., from Cifkurt Ticaret ve Sanayai, Istanbul, Turkey, for 86 Diesel-engined goods vehicles having low-geared rear axles. They comprise 66 "Comet 90" cruiserweight lorries and 20 "Super-Beaver" heavy-duty export vehicles. All the vehicles will be shipped to Istanbul in a completely dismantled condition. Bodies, mostly of timber, will be built in Turkey by a number of private firms.

DECCA RADAR LTD. announce that a contract for one of their airfield control radar equipments, type 424, has been placed by the Newcastle-upon-Tyne municipal authorities for Woolsington Airport. The firm add, however, that the equipment will not be installed until the end of next month.

THE ENGLISH ELECTRIC EXPORT AND TRADING CO., LTD., have obtained an order for a 250,000-kVA three-phase transformer bank from the Bonneville power administration for service on the 230,000-volt transmission system in the State of Oregon, U.S.A. It will comprise three single-phase units, each unit, complete with oil, weighing 150 tons. The transformer bank will have auto-connected windings for a voltage ratio of 230,000/115,000 volts, and a delta-connected tertiary winding for 13,200 volts will be included.

THE BRUSH GROUP announce that, subject to the grant of export licences, they are to supply to the Russian Government Corporation, Machinoimport, Diesel-engine driven electric generating sets, transformers and other electrical plant to the value of 3*l*. million.

LAUNCHES AND TRIAL TRIPS.

S.S. "SAXONSEA."—Single-screw oil tanker built by Kockums Shipyard, Malmö, Sweden, for the Oriental Tanker Corporation, Panama City, Panama. Main dimensions: 556 ft. 3 in. by 72 ft. by 40 ft.; deadweight capacity, 20,200 tons on a draught of 30 ft. 8½ in. De Laval steam turbine, developing 8,100 s.h.p. and a speed of 15½ knots. Trial trip, August 20.

M.S. "BOW SANTOS."—Single-screw cargo vessel, with accommodation for twelve passengers, built by Hall, Russell & Co., Ltd., Aberdeen, for Skibsaksjeselskapet Hassel (Owners: A/S Rederiet Odfjell), Minde, near Bergen, Norway. Largest vessel constructed at this shipyard. Main dimensions: 395 ft. between perpendiculars by 58 ft. by 37 ft. 4 in. to shelter deck; deadweight capacity, about 7,700 tons on a draught of 25 ft. 1 in. Doxford five-cylinder opposed-piston oil engine developing 5,500 b.h.p. at 112 r.p.m., constructed by Wilton-Fijenoord N.V., Schiedam, Holland, and installed by the shipbuilders. Launch, August 24.

M.S. "SUDAN."—Twin-screw cargo vessel, with accommodation for twelve passengers, built and engined by the Eriksbergs Mek. Verkstads Aktiebolag, Gothenburg, for A./B. Svenska Ostasiatiska Kompaniet, Gothenburg, Sweden. Main dimensions: 470 ft. between perpendiculars by 65 ft. by 40 ft. 6 in. to shelter deck; deadweight capacity, about 10,500 tons on a draught of 27 ft. 3 in. Two six-cylinder single-acting two-stroke Diesel engines, developing a total of 12,000 i.h.p. Speed, 17½ knots, fully loaded. Launch, August 25.

M.S. "GOLDEN BAY."—Twin-screw vessel for the carriage of cement in bulk, built by Henry Robb, Ltd., Leith, for the Tarakohe Shipping Co., Ltd., Wellington, New Zealand. Main dimensions: 245 ft. overall by 42 ft. by 18 ft.; deadweight capacity, about 1,100 tons on a draught of 12 ft. 6 in. Two four-cylinder Diesel engines, together developing 1,260 b.h.p. at 250 r.p.m., constructed by British Polar Engines, Ltd., Glasgow. Each engine drives one propeller through a magnetic coupling and alternator unit, manufactured by the British Thomson-Houston Co., Ltd., Rugby. Service speed, 10 knots. Launch, August 27.

M.S. "BURMAH SAPPHIRE."—Single-screw oil tanker, built by Swan, Hunter, and Wigham Richardson, Ltd., Wallsend-on-Tyne, for the Burmah Oil Co. (Tankers), Ltd., London, E.C.2. Main dimensions: 409 ft. 6 in. between perpendiculars by 56 ft. by 31 ft. 3 in.; deadweight capacity, 8,460 tons on a draught of 25 ft. 2½ in.; gross tonnage, 6,231; oil-tank capacity, 402,610 cub. ft. Wallsend-Doxford four-cylinder two-stroke opposed-piston oil engine, developing a maximum of 3,500 b.h.p. at 109 r.p.m., and designed to operate on heavy furnace fuel. Engine constructed by the Wallsend Slipway and Engineering Co., Ltd., Wallsend-on-Tyne. Service speed, 12 knots. Trial trip, August 30 and 31.

PERSONAL.

REAR-ADMIRAL (E) R. W. PARKER has been appointed for duty at the Admiralty, Bath, as deputy Engineer-in-Chief (administration), in succession to REAR-ADMIRAL (E) F. E. CLEMITSON, C.B., who is to be placed on the retired list on October 12. CAPTAIN (E) J. D. HAM has been promoted Rear-Admiral (E) as from September 28, and appointed for duty at the Admiralty as Director, aircraft maintenance and repair, in succession to REAR-ADMIRAL (E) G. C. ROSS, C.B., C.B.E., who is to retire on October 5. CAPTAIN (E) P. C. TAYLOR, A.D.C., has been promoted Rear-Admiral (E) as from September 28 and appointed an extra naval assistant to the second Sea Lord for engineering personnel, in succession to REAR-ADMIRAL (E) S. BROWN, C.B., who retires on October 5. ENGINEER CAPTAIN J. E. COOKE has been promoted Engineer Rear-Admiral as from September 28 and appointed to the staff of the Commander-in-Chief, Plymouth, in succession to REAR-ADMIRAL (E) R. W. PARKER, with effect from October 5.

MR. JOHN HARRISON, former area production manager in the South Western Division of the National Coal Board, has been appointed managing director of Cyprus Copco, Nicosia, Cyprus, the latest company to be established by the Atlas Diesel Organisation.

MR. S. W. RICHARDS, manager of the mines department of the General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2, since the formation of this department, retired on August 31. MR. P. H. NYE, manager of the company's business development department, is retiring on September 30 after 54 years of service with the company.

MR. T. A. HOLME, M.B.E., who was closely associated with the development and production of fabricated welded-steel structures in the electrical industry for the last 25 years, retired from the service of the British Thomson-Houston Co. Ltd., Rugby, on August 31.

MR. A. I. MACMILLAN, who has been district engineer at Crewe, London Midland Region, British Railways, since 1947, has been appointed assistant engineer (works maintenance), civil engineer's office, Euston, London, N.W.1.

MR. T. N. ADDISON has been appointed company secretary to Leyland Motors Ltd., Leyland, Lancashire.

MR. A. D. BAILEY has been appointed manager of the Newcastle branch of Brook Motors Ltd., Empress Works, Huddersfield.

The head office of the ASSOCIATION OF SUPERVISORY STAFFS, EXECUTIVES AND TECHNICIANS has been removed to Sutton House, 2-4, Homerton High-street, London, E.9 (Telephone: AMHerst 4792/3/4).

F. J. EDWARDS LTD., 359-361, Euston-road, London, N.W.1, have been appointed sole distributors in the United Kingdom for the entire range of the products of TANNER ENGINEERING LTD., woodworking-machinery manufacturers, Auckland, New Zealand.

PEST CONTROL LTD., Cambridge, have formed a subsidiary concern, the BRITISH STRADDLE CARRIER CO. LTD., 7, Chesterfield-gardens, Mayfair, London, W.1, to develop the sales of "Timber Wolf" and "Steelmaster" straddle carriers.

The firm of ROVER GAS TURBINES LTD. has been formed as a private company to manufacture, deal in, and carry on research and development work in connection with gas turbine and other machinery for use in vessels and aircraft. The subscribers are MR. S. B. WILKS and MR. L. FARMER.

The Bristol office of the ENGLISH ELECTRIC CO. LTD., Stafford, has been removed to 74-76, Broadmead, Bristol, 1. (Telephone: Bristol 27304.) The television and domestic-appliance service department remains at 155, Whiteladies-road, Bristol, 8. (Telephone: Bristol 38253/4.)

G. & J. WEIR, LTD., Cathcart, Glasgow, S.4, are removing their London office, on September 12, to Dunster House, 37, Mincing-lane, E.C.3. (Telephone: MANsion House 1985, is unaltered.)

VAUXHALL MOTORS LTD., Luton, have put in hand a 144,000-sq. ft. extension to their branch factory at Dunstable, Bedfordshire, the cost of which will be over 750,000*l*.

Owing to increases in the sales of contractors' plant, BUCKTON LTD., 63, Stockport-road, Ashton-under-Lyne, have formed a new concern, ERIC HEWITT & CO. LTD., to handle this side of their business. MR. J. S. FARNSWORTH, sales manager of Buckton Ltd., has been appointed works director of the new company which is operating from 63, Stockport-road.

The telephone number of the IRON AND STEEL BOARD, Norfolk House, St. James's-square, London, S.W.1, is now TRAfalgar 8833.

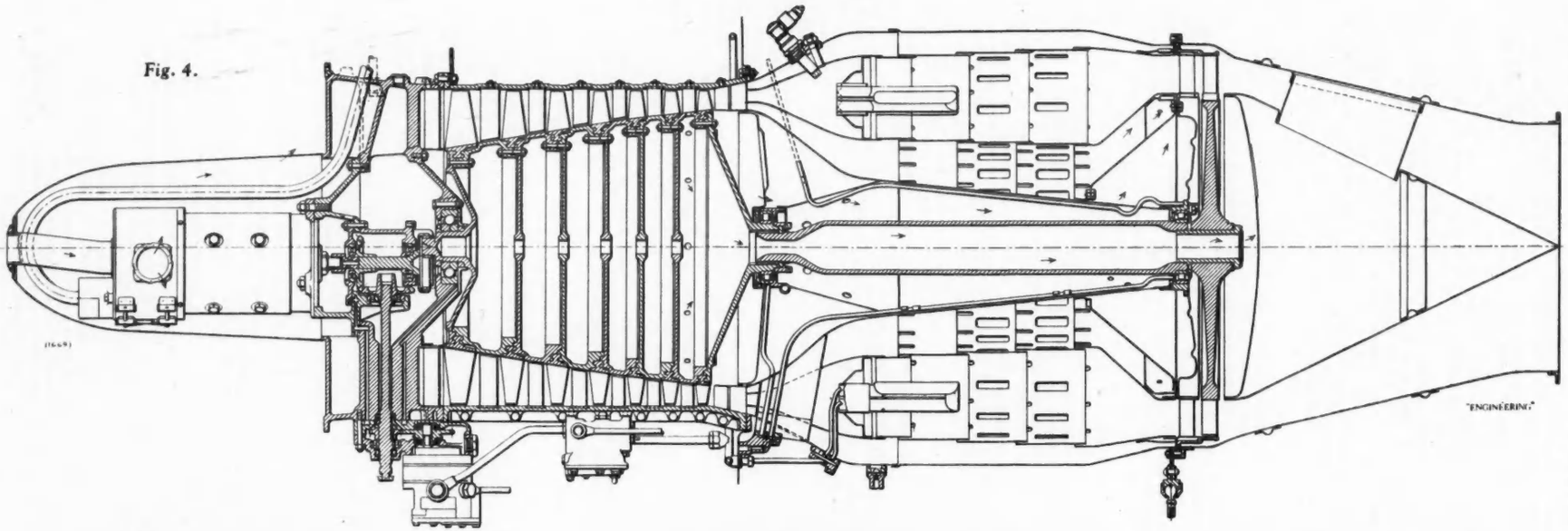
HONEYWELL-BROWN LTD., 1, Wadsworth-road, Perivale, Greenford, Middlesex, are to open officially their new factory at Newhouse, Motherwell, Lanarkshire, on September 18. It has been moved from Blantyre, Glasgow.

"VIPER ASV3" JET ENGINE.

ARMSTRONG SIDDELEY MOTORS, LIMITED, COVENTRY.

(*For Description, see Page* 329.)

Fig. 4.



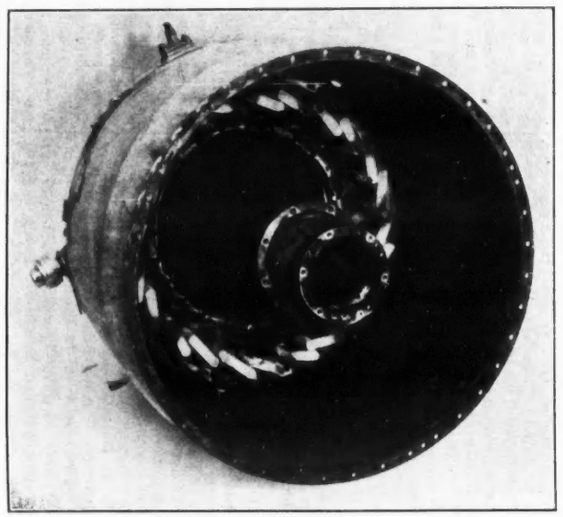


FIG. 5. COMBUSTION-CHAMBER CASING, SHOWING VAPORISING TUBES.

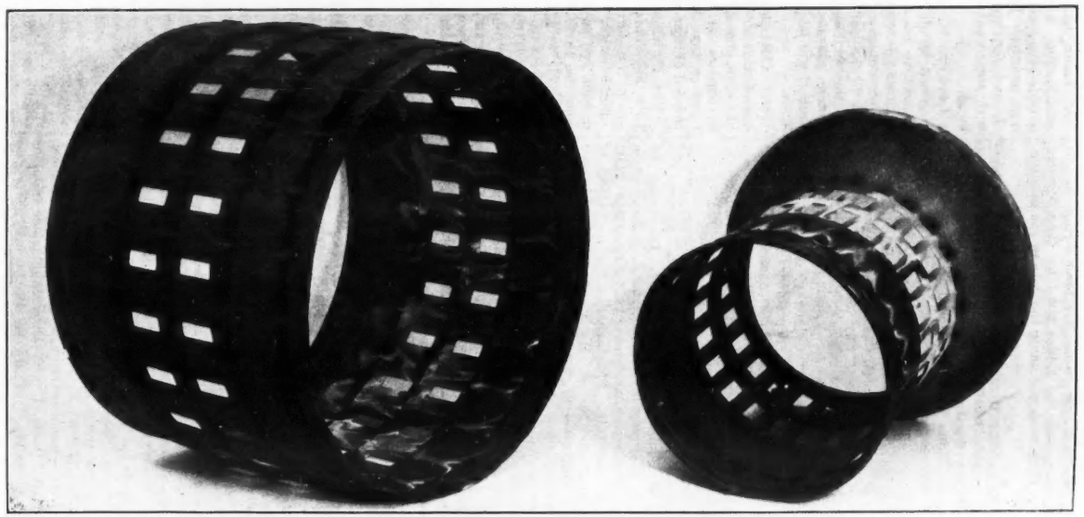


FIG. 6. OUTER AND INNER FLAME TUBES.

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The charge for advertisements classified under the headings of "Appointments Open," "Situations Wanted," "Tenders," etc., is 10*s.* for the first four lines or under, and 2*s.* 6*d.* per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 30*s.* per inch. If use is made of a box number the extra charge is 1*s.* per insertion, with the exception of advertisements appearing under "Situations Wanted." Series discounts for all classified advertisements can be obtained at the following rates:—5 per cent. for six; 12½ per cent. for thirteen; 25 per cent. for twenty-six; and 33⅓ per cent. for fifty-two insertions.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be received not later than first post Monday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received 16 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.

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Plate XXIII.—THE CORNISH ENGINE IN CORNWALL.

ENGINEERING

FRIDAY, SEPTEMBER 11, 1953.

VOL. 176. No. 4572.

TIMBER IN ENGINEERING.

FOREST products is evidently an alternative name for timber, as it is with this latter substance that the Forest Products Research Laboratory, at Princes Risborough, appears to be wholly concerned. Timber and its properties are of importance in many branches of engineering, and the latest report* of the Research Board contains information relating directly to difficulties encountered in connection with boat-building, structural work, electrical transmission, and aircraft. Many of the other matters dealt with, such as wood bending, machining and preservation methods will also have various engineering applications. The work on adhesives for composite wood and plywood, of importance to some of the Service Departments, will be of wide commercial interest.

In common with other reports from the outstations of the Department of Scientific and Industrial Research, comment is made on the fact that fundamental work is interfered with owing to "the heavy demand for industrial advisory work." In this case, however, it is added that, in spite of this, there has "been an increase in research work," although "there has been no change in the permitted complement of staff." When the Department of Scientific and Industrial Research was created in the course of the first World War the purpose was to assist in the awakening of a more scientific attitude of mind among industrialists and to facilitate the establishment of liaison between the laboratory and the workshop. These aims have been largely attained and the scientific awareness of British industry is now of a very different order from what it was in 1914. Even so, there still appear to be firms and individuals ignorant of the service which the D.S.I.R. has been designed to provide. The leaven, however, continues to work. In 1948, the number of technical inquiries dealt with by the Laboratory was 4,000; in 1950 it was 5,934, and in 1952 it was 6,300.

A section of the report which is likely to be of interest even to many who are not professionally concerned, deals with an inspection of the Cutty Sark, which was made as the result of a suggestion by H.R.H. the Duke of Edinburgh. This timber vessel is more than 80 years old and has been laid up for long periods and yet shows little evidence of fungal decay. This is in marked contrast to what has been found in fishing boats and pleasure craft, although in fishing boats decay does not appear to present a serious problem. In pleasure craft, however, it does. The difference is attributed to the fact that wooden pleasure boats are in use only at "infrequent intervals." Lying-up appears to "increase the risk of decay of the timber more than has previously been realised."

The long life of the Cutty Sark is in the main attributed to the extensive use of teak in its construction and the great thickness of the planking. The inspection of this vessel threw valuable light on one of the causes of breakdown in wooden hulls and decks. The effect resembles fungal decay in appearance but is due to electrolytic action caused by the presence of dissimilar metals in contact with moist wood. There is localised softening of the wood immediately adjacent to metal fastenings; this may lead to loosening of the fastenings known as "nail sickness." Many instances, particularly of small yachts, are on record in which the hull planking had to be renewed very early in the life of the boat. The Cutty Sark has teak hull planks of 4 in. to 6 in. thickness, secured to iron frames and iron diagonal bracing plates with yellow-metal bolts. Localised areas of both strong acidity and strong alkalinity were found inside the hull above and below the waterline, with local breakdown of the wood. That the vessel has survived so long is attributed to the resistance of teak to both acid and alkali attack and to the great thickness of the planking.

Different woods vary greatly in their susceptibility to this form of attack. Spruce, larch and pitch-pine, like teak, show good resistance; mahogany is fairly low in resistance and English oak very low. The report points out that in practice it is seldom possible entirely to avoid the use of dissimilar metals, but that in most cases it should be possible to insulate them, one from the other, with fibre or plastic washers or bushes. It is already common practice to coat large bolts, such as keel bolts, as well as the inside walls of the holes which are to receive them, with bitumen or chlorinated rubber paint, and it is suggested that the extension of this procedure to smaller bolts in smaller craft might prove well worth-while. If this were done, and care were taken to insulate thoroughly any electrical apparatus installed, so as to eliminate even very minute stray currents, then this particular type of trouble would not be likely to occur even if the least resistant timbers were used.

Some time ago the British Electricity Authority asked for advice in connection with the premature internal decay of transmission poles. Investigation has shown that they were not properly creosoted. A revised British Standard Specification has now been issued. Another electrical matter related to the decay of the wooden slats of cooling towers. The term "soft-rot" has been coined in connection with this phenomenon. Trouble of the same kind has been experienced in boats and timber structures immersed in sea or fresh water, but it is not thought to be of serious importance in those cases. For cooling towers, certain work has been carried out with the idea of using hardwoods, but some, on being leached, extruded a sticky gum which could not be tolerated in cooling water. It does

* *Report of the Forest Products Research Board with the Report of the Director of Forest Products Research for the Year* 1952. H.M. Stationery Office. [Price 3*s.* net.]

not appear from the report that the best way of dealing with this difficulty has yet been found; apparently wood impregnated with synthetic resin has given promising results.

The extensive work on plywood and composite wood has included long-term tests on adhesives. The tests were begun five years ago and consequently do not cover adhesives of recent introduction. With specimens stored under indoor conditions, sodium silicate is the only glue which has failed, although urea resins which have been extended with 50 per cent. or more of flour have weakened. For semi-outdoor exposure, in an unheated ventilated shed, casein and animal glue, in plywood, are considered likely to survive if condensation is absent; but for assembly joints under slightly less favourable conditions animal and casein glues have failed and urea glues have weakened considerably. With full weathering, only phenolic and resorcinal glues have survived. An examination of three Mosquito aircraft wings and one Canberra aircraft fin to ascertain if age or service had deteriorated the glued joints led to the conclusion that any deterioration of the glue was completely masked by the variation in workmanship in the original making of the joints.

As has been the case over a number of years, work has been done on the identification and testing of Colonial timbers, some of which are tending to replace traditional timbers now expensive or in short supply. The subject is of particular interest to furniture manufacturers, but some of these new woods are likely to be of wider application. Some are being used in building work, particularly for flooring, and trials are being carried on, in collaboration with the Plywood Research Panel, to ascertain their suitability for plywood manufacture.

NOTES.

WORLD AIR SPEED RECORD.

On the eve of the opening of the Society of British Aircraft Constructors' annual flying display at Farnborough, Squadron Leader Neville Duke secured for Great Britain the world air-speed record over a 3-km. course (subject to confirmation), in a Hawker Hunter aircraft powered by a Rolls-Royce Avon engine equipped with reheat. The Hunter reached an average speed of 727·6 m.p.h. on the speed course over the sea near Littlehampton, Sussex. The existing official speed record of 698 m.p.h. was established by Captain James S. Nash, of the United States, in a North American Sabre aircraft in November, 1952, but in July this year Colonel W. F. Barnes, also of the United States, achieved an average speed of nearly 716 m.p.h. in a Sabre aircraft; this record has not yet been confirmed by the Fédération Aéronautique Internationale (F.A.I.). The new speed over 3 km. achieved by the Hunter aircraft exceeds the unconfirmed American record by more than 1 per cent., which is the minimum margin recognised by the F.A.I. The other conditions governing the world air-speed record over a 3-km. course at a restricted altitude are, briefly, that the straight course over which the aircraft is flown must be measured with a degree of accuracy not less than 1/5,000 and must be approved by the F.A.I. (In the present attempt, the course was the same as that used in the successful 1946 record attempt.) At each end of the course, a straight approach of at least 1,000 km. must be indicated by pylons. The aircraft must not exceed a height of 100 m. while over the 3-km. course, and throughout the whole of the record flight must not exceed a height of 500 m. The aircraft must fly over the measured course twice in each direction, and the average of four consecutive runs is taken to be the speed achieved. The margin of error in determining the speed must not exceed ±2 per cent. On September 7, the speeds attained by the Hunter for the four runs were 716·7 m.p.h., 738·8 m.p.h., 716·5 m.p.h. and 738·6 m.p.h. The method of measuring the speed in the present attempt was by recording the aircraft photographically as it passed two marker points registering with the extremities of the course, in conjunction with an electronic timing mechanism of high accuracy.

FUEL CONSERVATION.

The theme of the productivity report on Fuel Conservation, published this week by the British Productivity Council (price 5*s*.) is that this country must save more coal or perish in the battle for world markets. The report asserts that the nation cannot continue to waste 80 per cent. of the heat available from the coal, which is already only being won under difficulties. The team who visited the United States to study methods being employed there state that this country already knows as much about fuel conservation as the Americans, but does not exploit that knowledge to the full. It has been estimated that the manufacturing industries could effect a saving of 30 per cent., and figures show that about ten tons of excess air pass through many inefficiently-operated boilers every hour; there are 120,000 Lancashire boilers in the United Kingdom. In homes, 25 per cent. of the heat escapes through the roof, and in the production of electrical energy in a condensing cycle there is a wastage of over 70 per cent. The railways, too, come in for a share of criticism, 13·5 million tons of high-volatile fuel being consumed by the locomotives at an average efficiency of 6 per cent. Locomotive coal consumption in America has been reduced from 125 to 94 lb. per 1,000 gross ton-miles by raising steam pressures, extending the use of graded coal sizes, using automatic stokers, and making greater use of roller bearings. The team regard the need for fuel advisory services and conservation as a State responsibility; they suggest the integration of gas and electricity works on the same site, to enable generation of power from gasworks waste heat or from an orthodox power plant using coke breeze, both supplying power to the grid, and the supply of pass-out steam from a generating station to a gasworks. Some of the questions they ask are: is it in the national interest that electricity should be used for space heating? Is it not essential that the functions of electricity be confined to the provision of power, light and only specialised heat processes? Is not gas the right fuel to retain on tap for space-heating purposes—i.e., occasional heating. Where electricity is available, should gas lighting be used for public services? The report amplifies these points further in 40 written recommendations. It advocates that the Government should show that they realise the importance of the country's almost complete dependence on coal for at least the next 30 years by taking appropriate measures to encourage fuel conservation. Since the report was compiled the Government have implemented the recommendation of the Ridley Committee that an Industrial Fuel Efficiency Organisation should be created, and the British Productivity Council have accepted responsibility for its initiation.

NATIONAL RADIO AND TELEVISION EXHIBITION.

Although radio occupies the first place in the title of the National Radio and Television Exhibition, television plays the leading role at Earl's Court. It is followed at no great distance by navigational aids and industrial and medical electronic devices of many kinds. Considerable interest is being taken in the Army and Royal Air Force exhibits, which include a full-sized layout of an anti-aircraft gun position. The careful planning which is a feature of the greater part of this equipment is well illustrated on the stand of the English Electric Company, Limited, by a display showing the build-up of "the works" of one of their receivers. In this the vertical type of chassis of single unit construction is used and particular attention has been paid to simplicity of assembly and easy maintenance. Visitors to the stand of Mullard, Limited, have had an opportunity of seeing the precision work which is involved in the manufacture of valves, cathode-ray tubes, and electron guns. The General Electric Company, Limited, are exhibiting a new table television receiver which is equipped with a 14-in. rectangular tube, thus providing the largest picture of this size in a compact cabinet. The set incorporates a neutral density filter in the face of the tube to improve contrast and prevent halation. The tube and valves are protected from the effects of fluctuating mains voltage by barretter current control. The same firm is demonstrating the high standard of reproduction it is possible to obtain from existing apparatus. Generally speaking, the 17-in. rectangular tube, which was shown for the first time last year, is this time to be found on a number of stands, while models with 21-in. tubes are also on view. Another feature which is incorporated in more than one set is automatic picture control, by means of which contrast and brightness are maintained steady, and fading and flutter, such as that caused by aircraft, are reduced. Ultra Electric, Limited, are showing the air/sea rescue equipment which is known as "Sarah." This consists of a beacon transmitter which only weighs 6 oz. and can be carried in the airman's "Mae West." It also comprises a radio transmitter-receiver and battery with a life of 20 hours, so that the survivor can talk to the searching crews. The whole assembly is waterproof, temperature-proof and shock-proof. In the searching aircraft or launch the position of the survivor can be pin-pointed down to a few feet by a cathode-ray tube display. British Watch Timers, Limited, are exhibiting a watch-timing equipment incorporating a crystal controlled time-base and consisting of an instrument which prints a permanent record of the performance of a clock or watch movement on a paper strip. An indication of the rate of gain or loss in 24 hours is given as well as of any escapement or other faults which may be present. Roneo, Limited, are displaying a machine which shows how electronics can be used for the duplication of stencils. It consists of a photo-electric eye which scans the original and causes an electric spark to cut a facsimile on the stencil. There are 500 scanning lines to the inch.

LETTER TO THE EDITOR.

THE LATE MR. E. F. SPANNER.

To the Editor of Engineering.

Sir,—As one who has made a very close study of all the late Mr. E. F. Spanner's most valuable works on airships, may I be allowed to put into proper perspective the remarks in your obituary notice on page 212, *ante*?

You refer to large sums of money spent on the construction of rigid airships. In point of fact, the amount in question was not one-tenth of that spent on the Brabazon; R100 at least made the double crossing of the Atlantic, but the Brabazon is to be broken up without making the attempt. Out of R101 we still have two magnificent hangars, one at Cardington and the other at Karachi.

While it would have been real wisdom on the part of those engaged on that rigid airship programme to have paid attention to Mr. Spanner's detail criticisms, yet, if his main charges had been valid, the performances of the Zeppelins between the wars should have been impossible. The great advances made in heavier-than-air transport have only been accomplished by expenditures on which there is no hope of an economic return. Had only a fraction of the same expenditure been spent on the development of those types of airships of which Mr. Spanner approved, we should have to-day a world-wide airship service operating at a small fraction of the real costs of present forms of air transport, and at speeds greater than those of helicopters.

Yours faithfully,
W. N. Alcock.

57, Dumbuck-crescent,
Dumbarton.
August 31, 1953.

[Did Mr. Spanner approve of any type of airship? Our recollection is that his views were summed up in the title of another of his books.—*Gentlemen Prefer Aeroplanes*.—Ed., E.]

THE CORNISH ENGINE IN CORNWALL.

By W. K. V. GALE.

THE word "Cornish," applied to a steam engine, is indicative of type, or more accurately, of a particular operational cycle. The Cornish engine appeared in more than one form, and in its day it was to be found in use in many parts of the world. Its manufacture was not confined to the Duchy which gave it the name, but it was there that the engine was conceived and perfected. To the men of Cornwall, too, must go the credit for the development of an engine which, for 25 years, was supreme in its field. Richard Trevithick was responsible for evolving the engine out of the older steam engines which he knew as a young engineer at the Cornish mines, but credit is also due to the mine captains* John Davey and Joel Lean, who published accounts of the performances of various engines and so stimulated competition among engineers to raise the standard of their work. The Cornish engine also owes much to the work of Arthur Woolf, another Cornishman, though he is best known, perhaps, in connection with compounding. These men, the pioneers, were followed by a worthy band of local engineers. William West, Samuel Grose, William Sims, the Michell family, Michael Loam and his son Matthew, and others carried on the tradition, and turned out many fine engines.

Behind all the developments leading to the remarkable performances of the Cornish engine was the commanding figure of Richard Trevithick. His contributions to engineering progress were many, but the greatest of all was the introduction of high-pressure steam. This was to have a far-reaching effect on the history of steam power, and was the basis on which the Cornish engine operated. Trevithick's persistent advocacy of high-pressure steam brought him into conflict with many engineers, including James Watt, among whose engines Trevithick received much of his early training. Watt's engine, which dominated industry in the last quarter of the Eighteenth Century, was essentially a low-pressure machine, the boiler pressure being sufficient to support one or two inches of mercury, that is, about ½ lb. to 1 lb. per square inch above the atmosphere. According to the operating instructions,* when the engine was heavily loaded the pressure could be raised a little, though the user was cautioned that "It is never adviseable to work with a strong steam when it can be avoided, as it increases the leakages of the boiler and joints of the steam case, and answers no good end."†

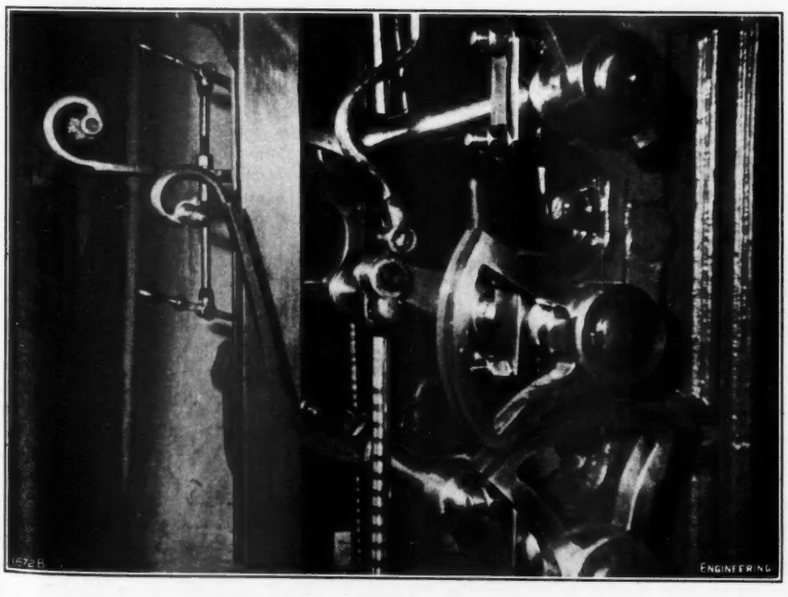
Watt's engine had reached a state of efficiency far ahead of that of its predecessor, the Newcomen, but it had become static, and further improvement seemed impossible. In 1798, Watt had stated that his engine at the Herland Mine, near Gwinear, was perfect, and that no further improvement could be expected.‡ To a limited extent, he was right. There was, in fact, little or nothing which could be done to improve the performance of his engines so long as steam pressures remained, as he insisted they must, at no more than a pound or two above the atmosphere; yet the basis on which considerable improvements could be made was well enough known to Watt—it was the principle of expansion, which he had patented in 1782. Working steam expansively had great possibilities, which, however, were of little more than theoretical interest while steam pressures were kept at about the atmospheric level. Some benefit could be derived by working expansively from low pressures to vacuum, but not much; high-pressure steam alone could bring out the full potentialities of the principle.

Trevithick was only a boy of six when the Watt engine first appeared in Cornwall in 1777, but by the time he was 19 he was employed as a mine engineer, and when he was 24 he fell foul of Watt by erecting an engine which infringed the separate-condenser patent. This patent, first granted to Watt in 1769 and extended by Act of Parliament for 25 years in 1775, effectively prevented Trevithick from doing much in the way of improving the condensing engine, but it did not stop him from producing a number of high-pressure non-condensing engines. The generation of steam at pressures of 40 lb. per square inch and upwards had thus already been achieved successfully by Trevithick when Watt's patent expired in 1800, leaving the Cornishman free to make an engine on Watt's plan, or to adapt the principle in any way he chose. But Trevithick, as always, had many schemes in hand in the early years of the Nineteenth Century, including some for locomotives, and it was some years before he availed himself of the opportunity of applying high-pressure steam to the condensing engine.

In 1812, however, Trevithick built an engine which was basically an orthodox Watt design—though it was inverted, with the beam below the cylinder—but which defied the established rule and worked with a boiler pressure of about 40 lb. per square inch. This engine was erected at Wheal Prosper,§ Gwithian, and was the first of the Cornish engines. It was in the use of high-pressure steam and a very early cut-off that the novelty lay. The inverted construction was of no special significance; other engines had been built in this way previously. The boiler pressure of about 40 lb. per square inch, and a cut-off of one-ninth of the stroke‖ were the

* By custom, a Cornish mine manager was known as "captain."

FIG. 1. ROSTOWRACK ENGINE ON ORIGINAL SITE.



F.G. 2. ROSTOWRACK ENGINE: VALVE GEAR.

* *Directions for Erecting and Working the Newly-Invented Steam Engine.* Boulton and Watt, 1779.

† *Ibid.*

‡ *Records of Mining*, by John Taylor, page 154 (1829).

§ "Wheal," commonly used as a prefix for the name of a mine in Cornwall, means a work, or working; the Cornish word for mine is "bal."

‖ *Richard Trevithick, The Engineer and the Man*, by H. W. Dickinson and A. Titley, page 128 (1934).

essential features of the engine, and high pressure and early cut-off were to be the basis of every Cornish engine which followed the Wheal Prosper pioneer. The engine was small, having a cylinder 24 in. in diameter by 6 ft. stroke, and steam was supplied by a boiler ". . . 24 ft. long from 5 ft. 6 in. to 6 ft. diameter, with fire Tube in the usual way."* It was, in fact, of the type which Trevithick had designed specially for high pressures at about the same time as the Wheal Prosper engine; with a boiler which has survived to prove its worth many times, and is still widely used under the name "Cornish."

Trevithick had established a principle, but he was not destined to carry the development of the Cornish engine any farther. A year or two after he had built the Wheal Prosper engine, attracted by the prospects of the high-pressure non-condensing engine in the mines of Peru, Trevithick left his native land, and Cornwall saw him no more for eleven years. When he did return, penniless, his El Dorado having proved legendary indeed, he found his Cornish engine well established. The example of the Wheal Prosper engine had not gone unheeded. Several Cornishmen had carried on his work, notably, in the early years, Arthur Woolf. Woolf had had certain initial successes with compounding, but was, perhaps, somewhat ahead of his time in this respect, and from 1824 onwards he devoted his whole time to perfecting the Cornish engine. It was in attention to detail, and in skilful construction, that opportunities for improvement were to be found; the principle of the engine had been established by Trevithick, and it never changed.

Woolf had the advantage of being a skilled mechanic as well as a good engineer, and all departments of engine work—design, building and operation—came under his careful supervision. By 1828, he was the most prominent engineer in Cornwall. Samuel Grose, too, was active at this period. His engine at Wheal Hope, built in 1825, was remarkable for the attention given to the insulation of all hot surfaces.† Here again was a principle which was well enough known, but to which proper attention had not been given. Grose carried the lagging of boilers, cylinders and pipes farther than ever before, with highly beneficial results.

The standard of performance of the Cornish engine was its "duty," or the quantity of water raised one foot high for the consumption of a bushel of coal. It was a standard which had been introduced in James Watt's time as a basis of comparison between his own engine and that of Newcomen. Confusion arose at times because, though the bushel was generally taken to equal 94 lb. of coal, there were differences of opinion on this point, and various estimates can be found, ranging from 80 lb. to 112 lb. The figure was stabilised at 112 lb. in 1856. Nevertheless, even before the weight of the bushel became subject to general agreement, "duty" was a simple and convenient standard. It was easy to calculate when the capacity of the pumps and the number of strokes made by the engine, while a bushel of coal was burned, were known. The interesting point about duty is that, since it was a measure of water raised for the consumption of a specified quantity of coal, it was an overall figure, which took into account the boilers, pumps, and pitwork, as well as the engine itself. The design and construction of all these items had to be of the best, therefore, in order to obtain high duty figures. The hand of Trevithick is to be seen in all the components of the complete pumping unit, and not only in the engine. His boiler, besides making possible the safe generation of steam at the pressures required, was also capable of much higher thermal efficiency than the older types. In the case of the pitwork and pumps, Trevithick had begun to apply the well-known plunger-pole pump in place of the common bucket pump as early as 1797. The invention was more than a century old when Trevithick began to use it—it had been patented by Sir Samuel Morland in 1675—and it was used in Cornwall to some extent from about 1786 onwards. The plunger-pole pump, however, was ideally suited to the Cornish engine, and Trevithick was quick to recognise the fact.

Running parallel with the work of Trevithick and his colleagues was the engine-recording of the Leans, which enabled the Cornish engineers to see what their compatriots were doing in the same field, and so maintained a healthy competition. The idea of publishing monthly records of the performances of engines originated with Captain John Davey, of Wheal Alfred, Gwinear, and he induced Captain Joel Lean, of Crenver and Oatfield Mine, Crowan, to undertake the work. Lean was a good choice. On his appointment as manager of Crenver and Oatfield in 1801, he found the engines and pitwork there in a very indifferent state of repair, and set to work to improve them. His success in this work saved the mine, and enabled it to operate at a profit instead of losing money, as it had been doing. Lean therefore brought to his office of engine reporter considerable practical experience, and a sound knowledge of what could be done by careful attention to detail. He and his sons, who followed him, filled the office of reporter in an able manner.

The first report appeared in 1811; it contained details of the work of only three engines. The beginnings were small, but the idea grew rapidly in popularity. By the end of 1811, 12 engines were being reported, and, as time went on, more and more engines came into the list. Lean's engine reports, bringing the performances of many different engines under the critical eyes of the Cornish engineers, could have but one effect. No man likes to appear at the bottom of a list; competition to produce an engine which would outshine all the others was keen, and some remarkable performances were recorded when new engines were brought into commission. Even the older engines were improved, and the overall effect was a raising of duty throughout Cornwall. Thus the Cornish engine came to assume its final form, the form in which it was recognised as doing its work ". . . at considerably less proportionate cost of fuel than any other engine."* Its supremacy was to remain unchallenged for a quarter of a century.

The Cornish engine, in its basic and most common form, is a single-cylinder single-acting engine, with the cylinder mounted vertically beneath one end of a pivoted beam, to which the piston rod is connected by means of an orthodox Watt-pattern parallel motion. A plug-rod connected to the beam between the trunnions and the piston rod operates the valves. At the opposite end of the beam, which projects from the engine house, is connected the pump rod, a heavy wooden rod descending into the mine shaft, and there operating the pumps. The latter will vary in number according to the depth of the mine, but all will be operated by the same rod. On the "outdoor" part of the beam, between the trunnions and the pump rod, is the connection for the air pump, and, usually, a small plunger-pole pump for feeding the boilers from the hotwell. The weight of the pump rod predominates, and causes the engine to make its "outdoor" stroke, thus raising the piston to the top of the cylinder.

The cycle then proceeds as follows: the steam valve opens, and steam at 40 lb. to 50 lb. per square inch enters the top of the cylinder, forces the piston down, and so draws the pump rod up and fills the pump barrels. This is what the Cornishman calls the "indoor" stroke, or "coming indoors." Any steam below the piston passes to the condenser through the exhaust valve, which opens slightly before the steam valve. The steam valve is closed well before the piston has made its full stroke; the point of closure is variable, and is under the control of the engine driver. In recent years, the practice in Cornwall has been to close the steam valve at about one-third of the stroke. The engine then works expansively, assisted by the vacuum created under the piston by the condenser. At the bottom of the stroke the exhaust valve closes and another valve, the equilibrium (in Cornish parlance the "Uncle Abra'am") valve, opens, to allow the steam to pass from above to below the piston. The weight of the pump rod now forces the plunger poles into the pump barrels, so raising the water to the surface, and the beam pulls the piston to the top of the cylinder again. This is the "outdoor" stroke, or "going outdoors." The exhaust valve then opens and allows the steam under the piston to enter the condenser. The steam valve opens once more, and steam is admitted to the top of the cylinder, causing the piston to descend again, assisted by the vacuum, and so the cycle continues.

The valves are all of the double-beat pattern (a Cornish invention, the work of Nicholas Harvey and William West in 1839) and three of them, the steam, exhaust and equilibrium valves, are operated

FIG. 3. BEAM OF ROSTOWRACK ENGINE.

* Dickinson and Titley, *op. cit.*, page 128.

† *A Treatise on the Cornish Pumping Engine*, by William Pole, page 63 (1844).

* William Pole, *op. cit.*, page 171.

THE CORNISH ENGINE IN CORNWALL.

(*For Description, see Page* 339.)

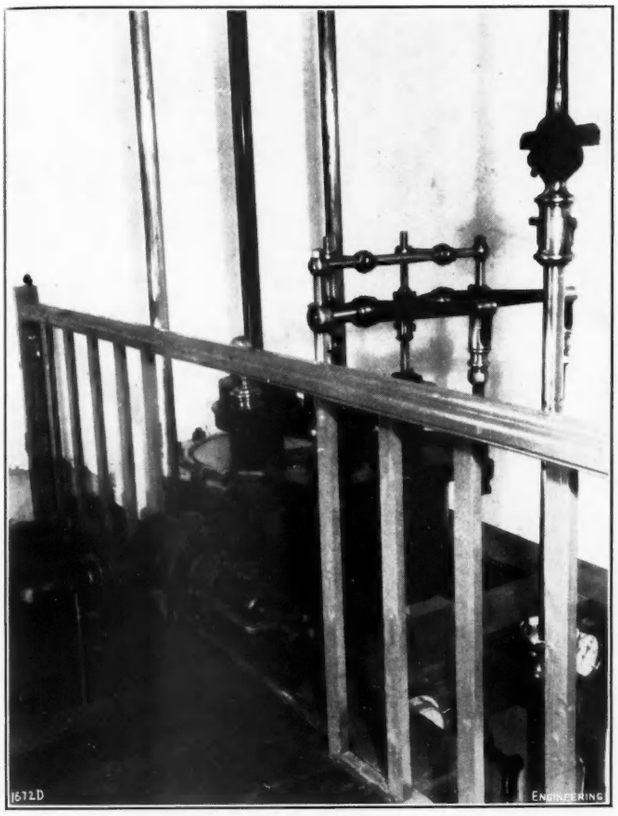


FIG. 4. ROSTOWRACK ENGINE: CYLINDER AND VALVES.

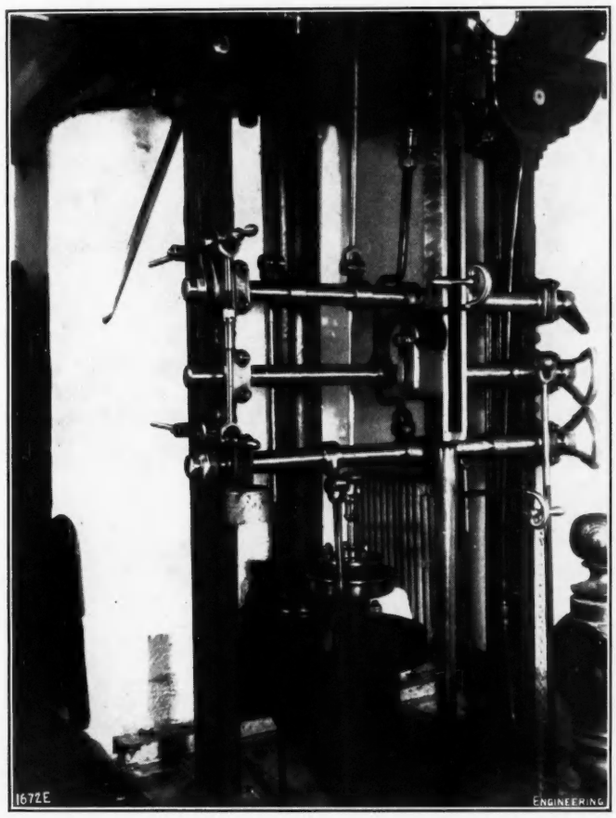


FIG. 5. ROSTOWRACK ENGINE: PLUG ROD AND VALVE GEAR.

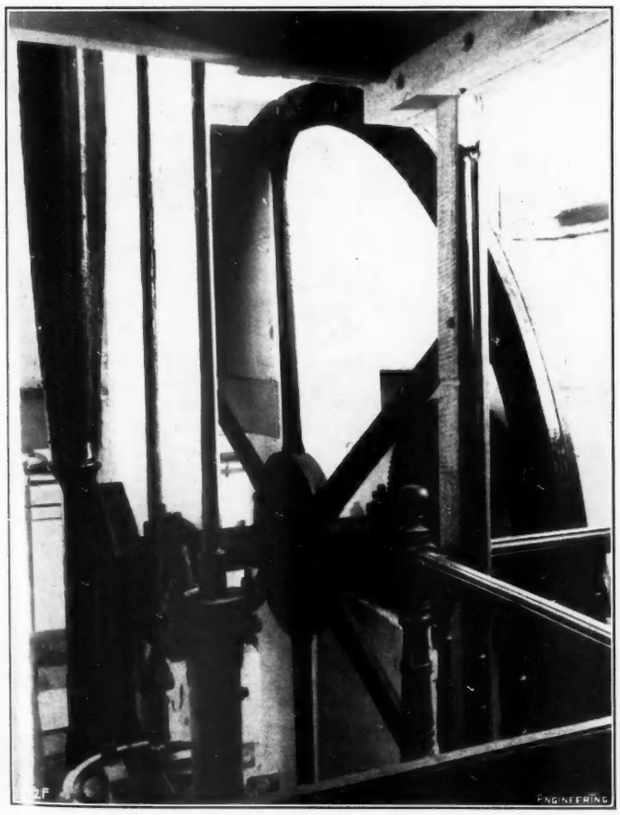


FIG. 6. ROSTOWRACK ENGINE: FLYWHEEL AND PUMPS.

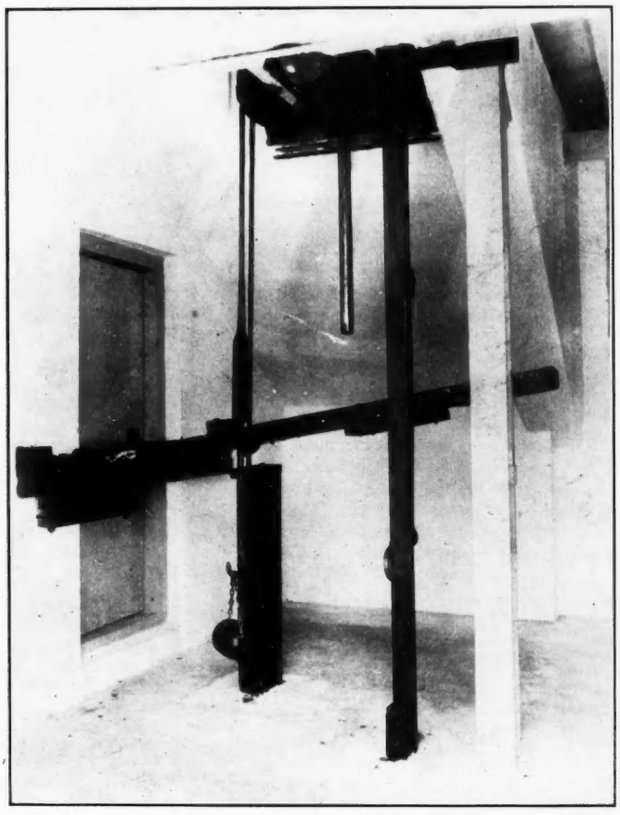


FIG. 7. ROSTOWRACK ENGINE: GEAR ON GROUND FLOOR.

(*To face page* 340.)

automatically by the plug-rod. The fourth, which has the slightly misleading title of "governor" valve, is solely a throttle valve, and is under the control of the engine driver. Interlocking quadrants are provided to prevent the exhaust and equilibrium valves from opening simultaneously. Each valve (except the governor) is counterbalanced to remain open, and is closed by a tappet; a catch engages a quadrant to keep the valve closed. At the correct point of the stroke, the movement of a cataract rod releases the catch, and allows the valve to open. It is by means of the cataract that the speed of the engine is controlled, for it causes a delay in the opening of the valve; the longer the delay, the fewer the number of strokes per minute.

The cataract is an old device, older by far than the Cornish engine. Watt, in fact, found it in use in Cornwall when he introduced his own engine there. In its early form the cataract consisted of a balanced tank, usually of wood, into which water flowed from an adjustable orifice until it filled the tank, sufficiently to overturn it. The water then poured from the tank, which was returned to its upright position by balance weights. The movement of the tank could be used to control a catch or valve of any description, and the rate of operation could be varied at will simply by altering the size of the filling orifice. The use of the cataract was by no means confined to controlling steam engines. Specimens of "tumbling box" cataract have been seen in use for taking samples of tin slimes from a launder or gutter at regular intervals, within recent years. The cataract used on the Cornish engine, though it is similar in principle to the old balanced box, consists of a small plunger-pole pump which is filled on the upstroke of the beam and emptied by the weight of the cataract rod forcing the water through a valve controlled by a hand-wheel. Some Cornish engines had one cataract, others had two. If one cataract was used, the engine paused at the end of its equilibrium stroke; this was the most common arrangement. The use of two cataracts caused the engine to pause at the end of each stroke.

Such is the basic Cornish engine. The majority of the many Cornish engines built were of the type described, but the Cornish cycle was applied to both the compound pumping engine and the rotative engine as well. An example of the former is provided by the great engines at Haarlemmermeer in Holland, built by Harvey and Company at Hayle in 1843 and 1847; there were three, but now only the Cruquius engine survives. They had the unusual arrangement of one cylinder inside the other; the high-pressure cylinder was 84 in. in diameter and the low-pressure 144 in., an annular piston being used for the latter. The Cruquius cylinders were, incidentally, the largest ever made for Cornish engines. The Cornish cycle was also applied to the more orthodox engine with two cylinders side-by-side; and there are examples of compound engines with the same steam cycle, but with the cylinders arranged horizontally and in tandem. Of the rotative type of Cornish engine, that formerly at Rostowrack china clay pit, and now in the museum of Messrs. Holman Brothers, Limited, at Camborne, is a good example. It is being presented by Lord Falmouth to the Cornish Engines Preservation Society at a ceremony to be held in Camborne to-morrow, September 12. Illustrations of the engine on its original site are given in Figs. 1 and 2, on page 339, and as erected in the museum, in Fig. 3, on page 340 and Figs. 4 to 7, on Plate XXIII.

How many Cornish engines were built, it is impossible to say. The engine was for a considerable number of years the standard machine for mine drainage and waterworks pumping, and many were built in various parts of the country, and indeed, in numerous places overseas as well. Even within the boundaries of Cornwall, no accurate statement of the number of engines can be made. The progress of the engine in Cornwall, however, is well illustrated by the fact that in 1836, only 24 years after Trevithick had established the principle at Wheal Prosper, 61 engines were recorded at work in the Duchy.* The effect of the work of the various engineers on the performance of the engines can also be seen from the published reports. Duty figures are not entirely reliable, as it is not always certain that the customary bushel of 94 lb. was being used in the calculations, but the reports give a good general idea of the rising efficiency over a number of years.

The computed duty of a Newcomen engine was 5·59 millions in 1769, and the Watt engine was averaging about 20 millions in 1800, when Watt's connection with Cornwall ceased.† By 1836, the work of the Cornishmen had taken effect, and the average duty figure for that year was 46·6 millions. For the first few years of the Nineteenth Century there was no improvement; in fact, there was some retrogression. For a few years after the Soho partners had left Cornwall, taking their best men with them, engines were neglected, and duty figures fell in consequence. In 1812, the average duty was poor, being 19·3 millions, but after that it began to increase, which was a reflection of the work of Trevithick. The published averages, of course, took into account engines which were old, or not so well cared for as they might have been, and these, by a poor performance, brought down the overall figure.

Individual figures as well as averages are given in the reports, however, and they show that certain of the most celebrated engines performed duties well above the average. One, in fact, was so good that it caused many engineers to express their doubts about the accuracy of the reports. This was Austen's famous 80-in. engine at Fowey Consols Mine, for which the principal engineer was William West. Because of the incredulity of some of the engineers, it was decided to hold a trial of the engine in public, and to have it conducted by independent observers. The trial took place in October, 1835, and as a result the duty of the engine was declared to be no less than 125,095,713.

Wicksteed,* who was sent to Cornwall to investigate the claims made for the Cornish engine on behalf of the East London Water Works Company, offers an explanation of the very high duty figures which were recorded for some of the engines. Mine-pumping engines were always erected with sufficient power to allow for deepening the mine, and the increased water load which would result. Consequently, while they were new, as Austen's was, and lightly loaded, they could work with a very short cut-off indeed. A high degree of expansion, coupled with excellent condition, good lagging and careful operation, could account for the remarkable duty of the engine. Perhaps Austen's engine was working under favourable conditions which it would be difficult, if not impossible, to maintain. Nevertheless, Wicksteed, whose investigations extended to other Cornish engines and Boulton and Watt engines, became convinced that the Cornish engine was 2¼ times as efficient as its predecessor, and he reported in favour of installing one at his company's water works. His recommendation was adopted, and the engine installed for the company at Old Ford—incidentally, it was a secondhand one from a Cornish mine—became a show-piece. From then on, the fame of the Cornish engine was assured,

Pole† sums up the Cornish engine by listing the features which enabled it to perform so well. They were: high-pressure steam; the degree of expansion; good design of exhaust valve, eduction pipe and all passages to the condenser, so that the vacuum in the cylinder was as nearly as possible that in the condenser, which was not always the case with the older engines; the fact that the condensed water from the steam case was returned to the boiler; and the care taken to economise heat in every way, not only by proper lagging, but by firing the boiler carefully, and attending to such obvious matters as not allowing the safety valve to blow off unnecessarily. Some of these things, said Pole, might be considered as trifles, but each and every one contributed its share to the successful and efficient operation of the engine.

An example of the care given in Cornwall to matters which were often considered as unimportant elsewhere is provided by the method of manning the engine. In many parts of the country it was customary to leave the firing of the boiler to an

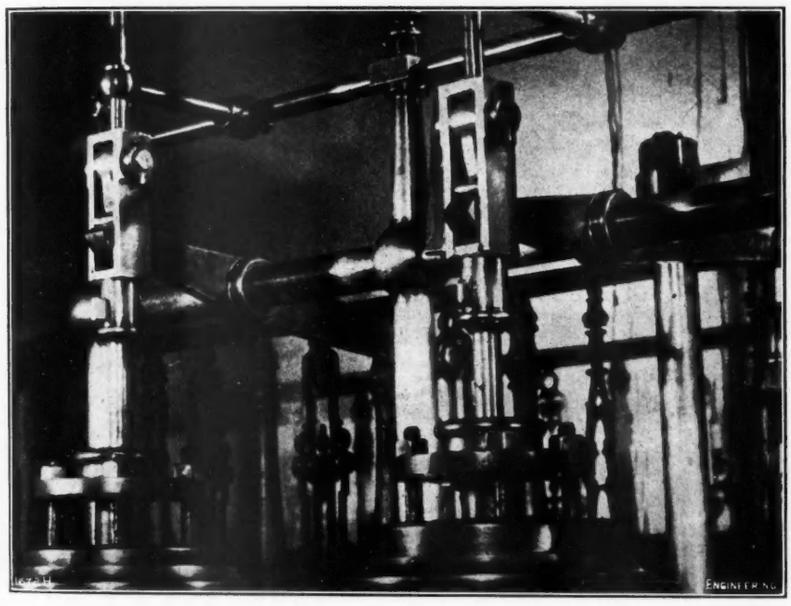


FIG. 8. VALVES OF TAYLOR'S SHAFT ENGINE.

* *Historical Statement of the Improvements made in the Duty performed by the Steam Engines in Cornwall*, by Thomas Lean and Brother, page 133 (1839).

† John Taylor, *op. cit.*, pages 153-4.

* *An Experimental Enquiry into . . . the Cornish and Boulton and Watt Pumping Engines*, by Thomas Wicksteed, pages 24-5 (1841).

† William Pole, *op. cit.*, pages 159 and 171-4.

unskilled labourer. Such a course, with its obvious opportunities for waste of fuel, was not adopted in Cornwall. There, the engine driver had charge of the boiler as well, and did his own firing; it was not too heavy a task if the engine was well up to its work. There was no question of dividing the responsibility between the engine and boiler rooms, and hoping that the attendant in each would give of his best; nor was there the tendency, so often seen elsewhere, to regard boiler firing as needing nothing but the ability to shovel coal. In Cornwall, boiler firing was recognised as requiring skill and a knowledge of engine working, and it was entrusted to the obvious man, the engine driver. He was given a boy to assist him with the incidental tasks, and he and his assistant worked an eight-hour shift.

When the decline of the Cornish engine came, it was through no fault of the engine itself. By the 1870s, Cornish mining had fallen on bad times and many mines closed down, their engines often being broken up for scrap. From then on, both in Cornwall and elsewhere, the age of the Cornish engine began to draw to a close. The high and increasing cost of coal, and the development of alternative methods of pumping, some of them reducing the labour demands to one man per shift, or even dispensing with labour altogether except for maintenance, and all of them cheaper to operate, were a challenge which the Cornish engine could not meet. It held its own for a time, and Cornish engines can still be found at work to-day, but the end is inevitable.

In 1935, a small group of enthusiasts, concerned at the rapid decline of the Cornish engine in the land of its origin, formed a committee (soon to become the Cornish Engines Preservation Society) to see what could be done to save some typical engines. The Society worked under difficulties then, as it does still, not the least of which was lack of the necessary funds, but it achieved certain initial successes. In 1945, the Society published a survey of the remaining pumping and rotative engines still in Cornwall. The survey disclosed that, although the total number of engines in Cornwall was quite small, it included some very fine examples still at work. The position was not entirely unsatisfactory, for the engines still at work were in very good condition, and of those no longer used, two were the property of the Society. The survey was reprinted in 1950, at which time it showed no change, and no detailed list has been made public since.* A private investigation shows, however, that, at the present time, the position is not so promising, having improved in one respect only, and worsened in several others.

The largest engine now at work in Cornwall is the 90-in. Harvey engine at Taylor's Shaft, East Pool Mine, near Redruth. This engine, which was built in 1892 for Highburrow East Shaft, Carn Brea Mine, was removed to the then new Taylor's Shaft in 1924, and has worked there ever since. East Pool Mine is no longer in operation, and the engine is the property of the Cornish Engines Preservation Society, but it is still at work, helping to drain the neighbouring South Crofty Mine. It is worked by arrangement between the Society and the mine management, and is only operated from 10 p.m. to 2 p.m., being idle for the rest of the 24 hours. It is drawing from 1,034 ft. in four lifts, and makes 3½ strokes a minute. Taylor's engine is a fine example of normal Cornish engine practice, and can be seen at work; but its active life is limited, as it is due to cease operation when electric pumps, now on order, are installed at South Crofty. The steam pumping equipment at the latter mine itself now consists of one engine only, Robinson's 80-in. The 90-in. Harvey engine, designed by Matthew Loam about 1878, which formerly worked at New Cook's Shaft, was virtually destroyed by an accidental breakage of the beam on December 28, 1850.* The damage was so extensive that it became uneconomic to repair the engine, and it is now being broken up for scrap. This was one of the engines recommended by the 1945 survey for preservation, but any hope of making suitable provision for its future was lost when the accident occurred.

Robinson's engine, on the other hand, is still at work for 24 hours a day, though it is now 99 years old. It is one of the oldest and most interesting engines in Cornwall. Designed by Captain Samuel Grose and built by Sandys, Vivian and Company at Copperhouse, Hayle, in 1854, it was first installed at East Wheal Alfred Mine, near Hayle. After two moves, first to Crenver and Wheal Abraham Mine, then to Tregurtha Downs near Marazion, it arrived at Robinson's Shaft, South Crofty Mine, in 1903, and there it has remained, giving little or no trouble, for half a century. Robinson's engine has a cylinder 80 in. in diameter and a nominal stroke of 10 ft. 4 in. The beam being equal-armed, the pump stroke is the same as that of the piston.

To-day, the engine works at 5½ strokes a minute, the actual stroke being about 9 ft. There are eight lifts of pumps in the shaft, excluding a small auxiliary pole 7 in. in diameter at the 24-fathom level† discharging at adit level, a total vertical distance of 130 ft. The main poles are: one 10-in. pole at the 335-fathom level, discharging at the 290-fathom level, a vertical distance of 267 ft.; six 14-in. poles from the 290-fathom level to the 36-fathom level, a total vertical distance of 1,370 ft.; one 15-in. pole at the 36-fathom level, discharging at a launder 12 ft. above the surface, a vertical lift of 396 ft. The delivery per pole per stroke, assuming a 9-ft. stroke and a 93 per cent. delivery to allow for clack slip, is, for the 10-in. pole, 28 gallons; for the 14-in. poles, 56 gallons; and for the 15-in. pole, 64 gallons. The water load per square inch of piston area is 26·4 lb.

Robinson's engine has several interesting features, and one which is unique as far as the existing engines are concerned; this is in the steam distribution arrangements. The ports for the live and equilibrium steam at the top of the cylinder are diametrically opposite, in short, they are as far apart as possible. The designer's intention was to avoid loss of heat from the live steam to surfaces cooled by equilibrium steam. He thus anticipated, to some extent, the later uniflow principle. Another unusual feature is the absence of a governor valve. The steam valve combines its own function with that of the governor, an arrangement which is common with all Grose's engines. Robinson's engine is a worthy monument to its designer, Samuel Grose, and, indirectly, to Richard Trevithick, whose pupil he was. The engine is to be shut down as soon as the electric pumping plant is installed, which may be very soon; pump chambers have been prepared underground, cables have been laid, transformers are in position, and everything is ready for the pumps when they arrive from the makers.

Only one other large engine was listed in the 1945 survey. This was the 85-in. engine at Wheal Busy, Chacewater, which was broken up for scrap in 1952. The engine was very much altered and rebuilt, and, as a result, was not of such great interest as some of the others mentioned in the survey. Its loss is to be regretted, however, for it was the last piece of mining machinery on a very historic site. Wheal Busy was working as early as 1700, and it has associations with Newcomen, Hornblower, Smeaton, Boulton and Watt, and many other engineers of local and national fame. Two more engines besides Taylor's at East Pool already belong to the Society. They are the 24-in. rotative winding (or "whim") engine at Levant Mine, near Land's End, and the 30-in. rotative winding engine at East Pool. Both engines are idle. They are both double-acting, and so are not proper Cornish engines, but both have unique features. The Levant engine was designed by Francis Michell and built by Harvey and Company at Hayle in 1840, and is thus the oldest existing engine in Cornwall. It has a cylinder 24 in. in diameter by 4 ft. stroke, and valves operated by eccentric gear; this is a later addition, the original arrangement being a plug-rod and plug handles. The East Pool winding engine was designed by F. W. Michell and built by Holman Brothers in 1887. It was the last rotative beam engine to be built in Cornwall.

Of the remaining six engines, all in the St. Austell district, which were listed by the 1945 survey, the

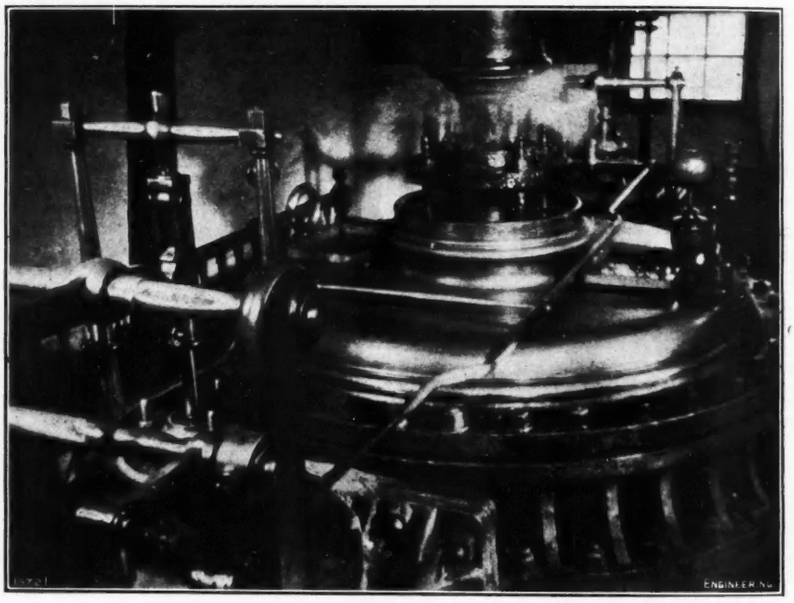


FIG. 9. ROBINSON'S SHAFT ENGINE: CYLINDER HEAD.

* At the time of writing, an illustrated survey is in course of preparation by the Cornish Engines Preservation Society.

* ENGINEERING, January 12, 1951, vol. 171, page 53.

† The Cornish mining fathom, like the nautical one, is 6 ft. The adit is the lowest level in a mine from which the water will drain away naturally. Most of the underground water is usually pumped to this level only.

position of three remains unchanged. These are the 50-in. pumping engine at Goonvean, built in 1863; the 50-in. Parkandillick pumping engine, dating from 1852, and the 30-in. engine at Greensplat, the origin and date of which are unknown. All three were at work in 1945, and are still at work, though the future of Parkandillick is doubtful. The remaining three engines in the 1945 list have all undergone changes. The 24-in. double-acting rotative engine at North Blackpool, idle in 1945, is now derelict, and the rotative engine from Rostowrack, as stated above, is in Messrs. Holman Brothers' museum at Camborne. The Rostowrack engine is single-acting, a heavy connecting rod or "sweep rod" being provided to take the engine "out of doors," that is, when it is making the equilibrium stroke. It has a cylinder 22 in. in diameter by 6 ft. stroke, an equal-armed beam of 10 ft. centres, and a single plug-rod. The parallel motion for the piston rod is of the crosshead and slide type, with a cast-iron crosshead and circular wrought-iron slide bars. The engine worked at 22 r.p.m. As erected in the museum, the engine is arranged to run on compressed air. Finally, there is the 40-in. Cornish pumping engine at Carpalla. This, a typical Harvey engine of 1863, was last worked in 1949, and its future is uncertain. It has been superseded in its work by electric plant, and owing to the fact that an extension of the clay pit under the site of the engine house is necessary, it could not stay where it is, even if it were to be preserved. There have been negotiations with the Science Museum, South Kensington, and some parts of the engine may finally rest there.

That is the position of the Cornish engine in Cornwall to-day. Four representative engines (Taylor's pumping engine, and the Levant, East Pool and Rostowrack rotative engines) are in the hands of the Cornish Engines Preservation Society, and at least one other very interesting engine (Robinson's) is in such good condition that it would be possible to preserve it without any great initial outlay. Only one, Rostowrack, is preserved under ideal conditions. It is in a heated building, under proper supervision, and arrangements have been made to admit members of the public on request. What can be done to ensure the proper preservation of the others is uncertain. That they cannot be moved is clear; at least, the larger ones, such as Taylor's, cannot. The engine weighs 125 tons, the beam alone being 52 tons in weight. If the boilers, pumps and other items, all of which are essential features of the complete pumping plant, are considered, the total weight is nearer 600 tons. Clearly, if such engines are to be preserved at all, they must stay where they are. Nor is it possible to leave them unattended indefinitely. Experience with Levant and East Pool winding engines has shown that atmospheric corrosion and the general effects of weather are by no means the only enemies; wilful damage has been done, especially at Levant.

There is a considerable amount of literature on the Cornish engine, and there are some excellent sound films available, made by the Shell Film Unit in 1946. These records are splendid as far as they go, but nothing can take the place of a real engine. The day of the slow, heavy prime mover is over, but there is much to be learned from these old engines. In the past, they astonished engineers with their performance; they can still impress, if only by the simple and elegant designs of their parts, and the massiveness of their construction. They can stand as a monument to good design, workmanship and durability, which gave them their just fame, and which, it need hardly be said, are just as vital now as they were in former days. Is it too much to hope that future generations of engineers can be shown something of the work of their forefathers in the land where so much good engineering originated? It is possible, if the right steps are taken now; but time is short.

THE BRITISH ASSOCIATION MEETING IN LIVERPOOL.

THE 115th annual meeting of the British Association, recently concluded in Liverpool, is the sixth to be held in that city, previous meetings having been held there in 1837, 1854, 1870, 1896 and 1923. This year's President, Sir Edward Appleton, G.B.E., K.C.B., F.R.S., continued a line of distinguished scientists who have presided over the Association's meetings in the great Merseyside port. Especially notable among them have been William Cavendish (1837), Thomas Henry Huxley (1870), Joseph Lister (1896) and Ernest Rutherford (1923).

INAUGURAL MEETING.

The inaugural meeting was held in the Philharmonic Hall, Hope-street, in the evening of Wednesday, September 2. In opening the proceedings, the Vice-Chancellor of Liverpool University, Sir James Mountford, M.A., D.Litt., explained that the Chancellor, the Marquess of Salisbury, K.G. was unable to be present owing to pressure of State duties, but had expressed the hope that the Association would have a very successful meeting. The Vice-Chancellor, continuing, said the University had great pleasure in admitting three eminent members of the Association to the honorary degree of Doctor of Laws and had been honoured by their acceptance. The Public Orator, Professor D. R. Seaborne Davies, then presented to the Vice-Chancellor the three members of the Association for the conferment of the degree. They were Sir Edward Appleton, President of the Association; Mr. Robert Birley, Headmaster of Eton and President of Section L (Education); and Sir Harold Jeffreys, Plumian Professor of Astronomy and Experimental Philosophy at Cambridge University and President of Section A (Mathematics and Physics).

The Lord Mayor of Liverpool, Alderman W. J. Tristram, J.P., welcomed the members on behalf of the City. He recalled that 30 years had elapsed since the previous meeting of the Association in Liverpool and said he had been told that the warmth of the City's welcome on that occasion was still remembered. Since that time there had been great changes in Liverpool and in the boundaries of science, but Liverpool's cordiality had not changed. The members, he thought, would be interested to see what had been done to stimulate the older industries in Liverpool and to develop new ones. He concluded by expressing the hope, on behalf of Liverpool and Merseyside, that the Association's deliberations would be fruitful to mankind.

In welcoming the members on behalf of the University, the Vice-Chancellor mentioned that Liverpool had welcomed the Association on five previous occasions and he was pleased to think that its third meeting there, in 1870, had contributed towards the movement which had led eventually to the founding of University College. He was also particularly gratified that the Association had come to Liverpool in the present year, during which the University was celebrating the jubilee of the grant of its Charter.

Sir Edward Appleton then delivered his Presidential Address entitled "Science for its Own Sake," which we reprinted, in abridged form, on page 315, *ante*. At the conclusion of the address, Professor A. V. Hill, who was President of the Association at the Belfast meeting last year, proposed a vote of thanks. In the course of his remarks, Professor Hill said Sir Edward had told him, some time ago, that his address would be entitled "Science for Fun" and he had then thought how well it would have been done and that it would be well worth doing. He agreed with Sir Edward's claim that the chief motive for scientific endeavour was curiosity and adventure; it was not philanthropy. The chief reward was not power or fame but the joy of the adventurer or explorer who got there first. Sir Edward had told an exciting story of the worlds that were being revealed by the new methods of radio—worlds which were inconceivably remote from any practical application for good or evil. As Principal of a University, Sir Edward was now, as he had said, an amateur scientist—one who worked for love. "Science for Love," he thought, would have been an admirable title for an admirable address.

After a brief response by the President the proceedings terminated. It was mentioned during the evening that the number of members registered for the Liverpool meeting up till that time was 3,350 but it was anticipated that the number would be materially increased during the following days.

SECTION G (ENGINEERING).

The sectional proceedings commenced on the following morning, Thursday, September 3, most of the sessions of Section G (Engineering), with which we are concerned, being held in the Walker Engineering Laboratories of the University. The address to the Section by the President, the Rt. Hon. Lord Dudley Gordon, was, however, delivered in the theatre of the adjacent Arts Building, in order to accommodate the larger audience. The address was entitled "Engineering in the Next Two Thousand Years" and will be reprinted, in abridged form, in next week's issue of ENGINEERING. At its conclusion, the vote of thanks was proposed by Sir Ben Lockspeiser, K.C.B., F.R.S., who said the President had been right to draw attention to the fact that this country was living on its capital, which was decreasing rapidly. The second point in the address was the moral which the President had drawn to show that the days of trial and error and hit and miss were either over or nearly over. There had been a long period of empiricism but no scientist would dare to sneer at those who had brought the world to its present state in the techniques of manufacture, very largely due to informed and intelligent empiricism. However, that period was passing and what mattered now was that there should be a relentless scientific attack on the various problems to which the President had drawn attention. Such attempts to look into the future tended to induce a feeling of pessimism, and perhaps it was right that it should be so because Man was a very wasteful creature; he wasted his resources, squandered the wealth of the world and picked up anything he could find and used it in a wasteful manner. That could not go on, and it was good that we should be reminded of the continual fall in material resources. On the other hand, there should not be too much pessimism regarding the future because the history of science was the history of the unexpected. The unexpected would always come along, provided the problems were tackled in the right scientific spirit.

COMPUTING MACHINES IN ENGINEERING AND INDUSTRY.

After a brief response to the vote of thanks, the President said the remainder of the morning would be devoted to a discussion on the utilisation of computing machines in engineering and industry. The subject was introduced by Professor F. C. Williams, of the Department of Electrical Engineering at the University of Manchester. Professor Williams began by emphasising the essential usefulness of the machines and remarked that, despite their still early state of development, they were capable of revolutionising many design procedures. The machines were not, he said, concerned primarily with higher mathematics, but only with faster and faster arithmetic. The machine at Manchester had been designed and built by Professor Newman, of the Mathematics Department of the University, and himself. When built, the machine proved capable of about 100 man-years of human figuring during every week, so that there was not sufficient work available at the University to keep it fully employed. It had, however, been placed at the disposal of other universities, of industry, and of the public for the solution of their problems. This use of the machine by outside organisations had increased steadily and it had been found that, once organisations had made use of it, they called upon its services to an increasing extent as their awareness of its potentialities grew. Professor Williams continued by indicating that the University itself did not undertake the solution of problems submitted by external sources, but undertook the training of personnel from outside organisations, subsequently making the machine available to them for solving

their own problems. The period of training varied, of course, with the previous knowledge of the prospective operator, but an adequate standard could usually be attained in six months. Professor Williams concluded his introduction by emphasising that the value of the machine lay in its ability to permit the examination and re-examination of trial designs of a number and complexity far greater than had been practicable hitherto. He acknowledged that the machines could, and did, make mistakes, but he pointed out that, because of their high speed of operation, one mistake a day on the part of a machine corresponded to less than one mistake per annum on the part of a human computer. It was common for machines of the kind under consideration to make a million additions without error.

Mr. R. K. Livesley then presented his paper entitled "The Utilisation of Electronic Computers in Engineering Practice," which dealt with the use of digital computers in solving engineering design problems, with particular reference to the work done on the Manchester University machine. This paper is published on page 349 of this issue. Another paper, by Mr. G. G. Alway, was then delivered by the author giving an account of the increasing need for automatic computing machines in aircraft engineering and referring to some of the problems programmed for the Pilot A.C.E. machine at the National Physical Laboratory. This paper is published on page 351.

The two papers were discussed together. The first speaker, Dr. C. A. Maunder-Foster, suggested that it would be of interest if one of the machines could be put into reverse and a programme arrived at from the results. He asked if a computing machine could be employed to derive the expressions to be used in programming. In reply, Mr. Livesley said a computor would only do what it was told to do. It would not do mathematics, but it would do arithmetic according to a pre-arranged scheme; it would not tell the user how he ought to solve the problem. The machine would do the easy parts of the calculation, but it could not organise a calculation. The machine could not read algebra, and it was therefore necessary to translate the algebraic symbols into some sort of code and feed it into the machine on a punched card or tape.

Mr. R. H. Sorrell asked if it were possible for a computing machine to check itself by working backwards to give the original data and if so, whether there were occasions when it did not check. To this, Mr. Alway replied that normally the machine did its own checking, and the check applied was more or less the same as in human computing, namely, by doing the problem in another way. There were, of course, occasions when it did not check. The next speaker, Mr. J. N. Desmond, said he had been trying to arrange an air-line timetable involving 473 variables—a linear problem—and he had been told that to solve it the capacity of the computer would have to be much greater than that of any machine built so far. There were, however, possible simplifications in the equations to which not more than five variables occurred at any one time in any one equation, and the problem consisted in selecting 288 variables out of the 473. Basically, it was a matter of solving 288 equations in 288 variables, but the fact that only five variables were used in any one equation at a time might help.

Replying, Mr. Livesley said he knew nothing about linear programming and added that the word was often used with different meanings. When it was said that a problem could not be done on a typical computer, it meant either that it was not known how the problem should be tackled or that the computer was not large enough or fast enough. If there were a mathematical scheme whereby the calculations could be done, a programme could theoretically be made up for some computer which might not have been built, but generally speaking computers were being built to deal with such problems. Existing machines, however, were capable of handling a great deal of useful work.

After a vote of thanks to the authors and Professor Williams, the session terminated.

(To be continued.)

LABOUR NOTES.

THE 34 members of the general council of the Trades Union Congress met in private at Douglas, Isle of Man, on September 3 and 4, to decide the attitude they would adopt at the annual conference which is being held this week. Although the council had prepared for submission to the Congress a long interim report on public ownership, some two hours were spent on September 3 on the discussion of a proposal put forward by the Amalgamated Union of Foundry Workers. This affirmed that "the crisis in Britain's economy can only be resolved by the rapid and scientific development of our total resources within the framework of an overall plan necessitating a very considerable extension of public ownership, embracing the principle of workers' control . . ." When a vote was taken after the discussion, only four members of the council supported the Foundry Workers' motion; 29 voted against and one member abstained. The motion, it was then decided, would be submitted to the Congress as an amendment to the report on public ownership.

Another proposal discussed on the first day of the meeting of the T.U.C. general council was a resolution put forward by the United Society of Boilermakers, to the effect that, should members of the general council accept positions on the new Iron and Steel Board or similar bodies, they should be asked to resign immediately from the council. This resolution also was opposed by the council. On the second and last day of the meeting a motion proposed by the National Union of Railwaymen, that there should be 50 per cent. representation of trade unions on the boards of the nationalised industries, was opposed by a large majority. It was then suggested that the motion be left to a free vote of the Congress but only three members of the council were in favour of this step.

On September 3, the Association of Engineering and Shipbuilding Draughtsmen met the Engineering and Allied Employers National Federation to present a claim on behalf of their members employed in federated firms for wage increases equivalent to 15 per cent. of the Association's present minimum wage scale, with the maintenance of all existing merit and other differentials. For men of 25 years of age and upwards, the increase claimed is stated to be equivalent to about 30*s.* a week. The persons affected by the claim are draughtsmen, designers, calculators, estimators, planning engineers and tracers. The Federation are still considering this claim but it was announced on September 4 that a request made on behalf of draughtsmen and various grades of scientific, technical and clerical staffs by a number of representative unions for a third week's annual paid holiday had been rejected by the Federation.

The Ship Constructors and Shipwrights' Association have placed before the legal committee of the Trades Union Congress a recent case heard at Sunderland County Court in which a shipyard employee was awarded 110*l.* damages against his employers, and the employers were subsequently awarded damages for a similar amount against a crane driver who was held responsible for the accident. The crane driver was ordered to pay the damages at the rate of 1*l.* a month. Trade-union circles are concerned at the possibility of this procedure being extended. Mr. F. W. Cook, Wear District delegate of the United Society of Boilermakers, commenting on the matter, said that it seemed that employees would have to apply for insurance to cover themselves against cases of this kind, but there appeared to be difficulties in obtaining such an insurance policy. The matter is also to be discussed by the Confederation of Shipbuilding and Engineering Unions.

Figures issued by the Ministry of Labour and National Service indicate that the total working population rose by 27,000 (2,000 men and 25,000 women) during July, namely, from 23,325,000 on June 30 to 23,352,000 on July 31. The total working population represents the estimated total number of persons, aged 15 and upwards, who work for pay or gain or register themselves as available for such work. The total comprises the Forces, men and women on release leave and not yet in employment, all persons in civil employment, including those temporarily laid off, and wholly-unemployed persons who are registered for employment. Part-time employees are counted as full units. The strength of the Forces on July 31 remained unchanged at 865,000, and ex-Service men and women on release leave who had not then entered employment numbered approximately 6,000. The number of persons registered as unemployed on August 10 was 293,500, including 11,100 temporarily stopped and, of the total, 121,200 had been unemployed for more than eight weeks. The figure of 293,500 represented an increase of 20,900 compared with the number of unemployed on July 13. It is pointed out, however, that the increase was mainly due to the number of young persons registering for employment at the conclusion of the summer school-leaving term. The figure of 293,500 for the unemployed on August 10 represents 1·4 per cent. of the estimated total number of employees, compared with 1·3 per cent. in July and 1·9 per cent. in August, 1952.

During July, the number of persons in civil employment, namely, industry, commerce and services of all kinds, rose by 24,000, from 22,190,000 to 22,214,000; all the new employees were women. In the basic industries, comprising mining and quarrying; gas, electricity and water supply; transport and communication; and agriculture and fishing, employment rose by 10,000, from 4,067,000 to 4,077,000, this being principally due to a seasonal increase in agriculture. Against this, however, there occurred a fall of 1,800 in the number of wage earners on the colliery books. There was a rise of 9,000 in the manufacturing industries, the main increase being a largely seasonal rise of 12,000 (from 872,000 to 884,000) in the food, drink and tobacco group of industries. This was partially offset by a decrease of 5,000, from 2,525,000 to 2,520,000 in the engineering, metal goods and precision-instruments group of industries. Employment in building and contracting declined by 8,000, from 1,448,000 to 1,440,000, during July. On the other hand, there were seasonal rises of 8,000, from 2,641,000 to 2,649,000, in the distributive trades, and of 6,000, from 3,991,000 to 3,997,000, in the professional, financial and miscellaneous-services group of industries, mainly in the catering, hotels and similar services.

The so-called "guerilla" strike, involving several thousand members of the Electrical Trades Union, at the time of writing, appears to be no nearer a settlement. On the contrary, it is extending, and R.A.F. stations and a civil airfield in Northern Ireland are now affected and hints have been thrown out that the strike may spread to Scotland. A proposal for what was termed "an immediate interim wage increase," put forward by Mr. W. C. Stevens, the general secretary of the union, who added that the executive committee might then be ready to refer the remainder of their dispute to arbitration, has been firmly turned down by the National Federated Electrical Association representing the employers. Speaking on behalf of the Association, the secretary and director, Mr. L. C. Penwill, said that the employers would in no circumstances prejudice the Industrial Disputes Tribunal in arriving at any proper award they saw fit to make. Mr. Stevens has stated that a maximum of 20,000 members of the E.T.U. might be called out but that it would take some weeks to reach this total.

Unemployment among Tyneside shipyard employees has fallen to 640, the lowest figure recorded since the war. The highest figure was 2,725 in April 1950, and the highest, this year, was 1,080 in April. There are more than 18,000 shipyard employees on Tyneside.

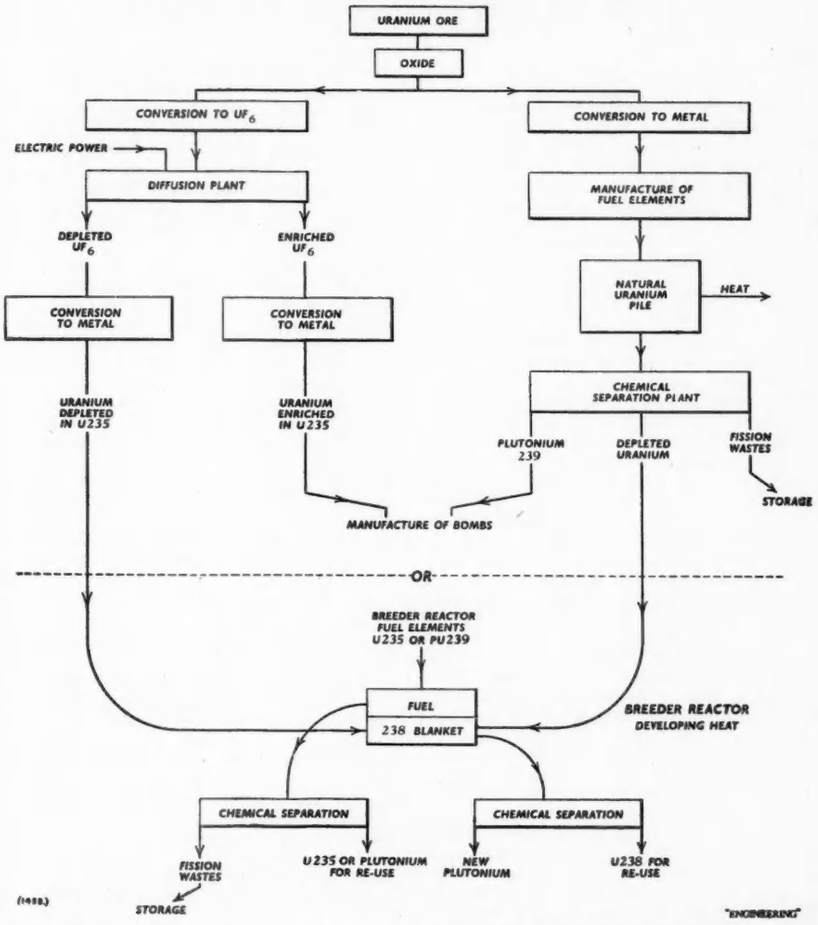
THE OUTLOOK FOR ECONOMIC NUCLEAR POWER.*

By B. L. GOODLET, O.B.E., M.A., M.I.Mech.E.

Introduction.—A prominent American engineer in a position to judge said recently† that "at the present stage of development nuclear fuel as a fuel is not competitive with conventional fuels. We do not know how to build a nuclear power plant to-day which will produce kilowatt hours cheaper than a coal, oil or gas-fired power plant of modern design, without crediting the operation with the value of plutonium produced at a price based on its military value rather than on its thermal or fuel value."

One must agree that nuclear-electric power will be economically sound only when it can compete with conventional electric power without support from a Government market for weapon material that may collapse at any time. However, the concept of "economic" nuclear power has a meaning only in relation to the cost of conventional power in a particular locality—and the cost of power in the United States is rather low by world standards. Our interest in nuclear power stems from the facts that the national demand for electricity seems likely soon to outstrip the national output of coal; that the economics of nuclear power may become more favourable as coal prices rise; and that there are many countries in which the *per capita* energy quota needed to raise the standard of living cannot be obtained from available sources of conventional fuels.

FLOW DIAGRAM OF WEAPON PROJECT WITH BREEDER REACTOR APPENDED.



World reserves of natural uranium metal have been put at 25×10^6 tons, equivalent to about 75×10^{12} tons of coal if we can use all of it, or $\frac{1}{1000}$th of this amount if we can use only the U235. World coal reserves are usually put at between 2×10^{12} and 6×10^{12} tons, or say 1,000 tons per head of world population; present average *per capita* consumption is around two-thirds of a ton per annum.* There is, therefore, no present world shortage of coal. Nevertheless, unequal distribution of resources and difficulties of mining, transport and finance create deficiency areas in which the possibilities of nuclear power are of real interest.

EXISTING ATOMIC WEAPON INDUSTRY.

Nuclear power will originate within the existing atomic weapon industry, in which the United States alone has invested over 4,000,000,000*l*. The business of this industry is to produce fissile materials for bombs; this may be either U235 separated from U238 in a diffusion plant or plutonium made from U238 in a pile (see the accompanying flow diagram).

Natural uranium contains only 0·7 per cent. of U235; the output of a diffusion plant is not pure U235, but material enriched in this isotope to such a degree that the fast cumulative chain reaction needed in a bomb becomes possible. A diffusion plant consumes very large amounts of electrical energy for driving thousands of pumps and compressors; for example, the power demand of plants in the United States has been stated to be 3,700,000 kW. If this electrical energy is generated from coal with a conversion efficiency of 25 per cent., the energy of the coal burnt may be not insignificant compared with the energy content of the highly enriched fissile material produced.* Nuclear power schemes fuelled from the output of a diffusion plant therefore require careful scrutiny from the standpoints of overall energy utilisation and costs, and are likely to be of only military interest, since the cost of electrical energy generated from such fuel may be of the order of 6*d*. per kWh., and the amount of fuel available very limited.

The function of nuclear reactors or piles is to convert U238 into plutonium—an artificial fissile element not found in nature. A nuclear reactor may be defined as an assembly of fissile and other materials the proportioning of which is such that a fission chain reaction can be developed under control. The heat released in a reactor can be converted into work by a heat engine. The action of a reactor is as follows: fission of a uranium nucleus releases energy and an average of $2\frac{1}{2}$ neutrons. In the bomb, the ideal is for all these neutrons to produce further fissions so that the number of fissions in the *n*th generation is $2\frac{1}{2}^n$. A simple calculation will show that the number of fissions in the 61st generation is then almost equal to the number of atoms in a kilogram of uranium, the fission energy of which equals the energy of some 5,000 tons of T.N.T. Since each generation will occupy only about 10^{-8} second the release of energy is explosive, as is required.

The action in a reactor is different. The fission rate is not cumulative but constant, each fission producing its $2\frac{1}{2}$ neutrons but only one other fission. Each fission thus leaves behind it $1\frac{1}{2}$ surplus neutrons which must not produce further fissions if the pile is to remain under control. These neutrons are disposed of by absorption into inert nuclei within the reactor and escape outside it. Escape and non-fission absorption are thus essential to stability. If too many neutrons escape or get absorbed, each fission will produce on the average less than one other fission and the chain reaction will die away or never get started. If too few neutrons escape or get absorbed the chain reaction will be divergent. Escape and absorption are thus competing processes—if one goes up the other must go down or the chain reaction will stop. Escape is a surface effect but fission occurs throughout the volume of the uranium. Volume varies as the cube, surface as the square of the linear dimensions. For similar shapes the ratio of volume to surface, and hence the ratio of fission captures to escapes, increases directly with the size. The critical size of a bomb or reactor is the size for which the production of neutrons by fission is just equal to their loss by escape and absorption. If the size is below critical a chain reaction cannot develop.

The absorption of a fission neutron into a nucleus adds one neutron to those already therein and gives the nucleus indigestion. It usually reacts by emitting a gamma ray and increasing its atomic weight by one, i.e., by becoming an isotope of its original self. If this isotope does not exist in nature it is invariably radioactive, which means that in time it will eject an alpha or beta particle and turn itself into another element. Neutrons are valuable and must not be wasted. One should therefore try to arrange matters so that the end product of neutron absorption is valuable. There are two ways of doing this: first, one can produce artificially radioactive isotopes of various elements which have many uses in science and in medicine; second, one can sometimes change one element into another having more desirable properties. It is in this way that valuable fissile plutonium is formed from the relatively inert uranium isotope 238. When situated in the intense neutron flux inside a reactor, U238 nuclei capture neutrons and become U239. These, in turn, eject two beta particles in succession, becoming first neptunium 239 and finally plutonium 239.

Production reactors use natural uranium, in which the relatively inert 238 isotope is 99·3 per cent. of the total, so that considerable ingenuity is needed to make the chain reaction go. The neutrons released in fission have energies around 10^6 e v. This is not high enough to produce much fission

* Paper read before Section G of the British Association at Liverpool, on Friday, September 4, 1953.

† Murray Joslin, Commonwealth Edison Company, Chicago, before the special Conference of the National Industrial Conference Board, New York, October 17, 1952.

* England holds the world's record of about four tons per head (excluding exports).

* Mining, in comparison, is quite an efficient process. The energy consumed in winning and raising a ton of coal (energy content 7,000 kWh) is not more than 50 kWh, or 0·7 per cent.

of the U238, so that maintenance of the chain reaction depends upon at least one neutron per fission surviving absorption and escape and finally producing a further fission in the relatively scarce U235. The probability of fission capture in U235 is greatest with neutrons that are moving rather slowly (energy around 0·03 e v.) in thermal equilibrium with the uranium atoms. The problem, therefore, is to slow the fission neutrons down to thermal energy, by repeated collisions with nuclei, without losing too many by absorption during the slowing-down process. This slowing-down cannot be done within the uranium because neutrons of intermediate energy, especially around 7 e v., are avidly captured by U238. The trick is to have the uranium in a lattice of parallel rods surrounded by a medium termed the moderator—in practice graphite or heavy water. Most of the fission neutrons then escape out of the uranium rods into the moderator; in this, they move around and get slowed down to thermal energy by repeated elastic collisions with moderator nuclei. When the neutrons finally diffuse back into the uranium they have lost so much energy that absorption by the plentiful U238 is unlikely but fission capture by the scarce U235 is very probable. The moderator has to be a light element that scarcely absorbs neutrons; the collisions are then elastic and the energy loss per collision high, so that slowing down requires the minimum number of collisions. A typical neutron balance for a graphite reactor is given in Table I.

TABLE I.

Neutrons produced in fission of 235 and fast fission of 238	2·56
„ carrying on the chain reaction	1·0
„ absorbed in U238 to produce plutonium	0·9
„ „ „ U235 to produce U236—wasted	0·2
„ „ „ the moderator—wasted	0·3
„ „ „ structural elements—wasted	0·05
„ escaping—wasted	0·09
„ invested in control system—wasted	0·02
	2·56

Rise of temperature increases wasteful absorption in fuel and moderator, and neutrons are also absorbed in the waste products of fission. Any increase of wasteful absorption during operations must be compensated by a decreased absorption in the control system. This is effected by a slight withdrawal of the neutron-absorbing control rods. In a heavy-water reactor, neutron losses in the moderator would be much smaller, resulting in a reduced minimum critical size—3 tons of uranium in 5 tons of heavy water, as against 25 tons of uranium and 650 tons of graphite.

From Table I it appears that each fission means the conversion of one atom of U235 into fission products and 0·2 atom into inert U236; the overall consumption of U235 is thus about 1·2 atoms per fission. For this we get 0·9 atom of plutonium, so that, in this reactor, we exchange four atoms of U235 for three atoms of Pu239. The fission heat amounts to about 22,200 kWh. per gram fissioned, i.e., 22,200 ÷ 1·2 = 18,500 kWh per gram consumed, or 24,000 kWh = 1 megawatt-day for 1·3 grams of U235 consumed. The reactor cooling system must be able to remove this heat at a safe temperature.

Each fission produces two fission product nuclei each of which contains on the average three neutrons too many for stability. Hence, each nucleus undergoes about this number of stages of beta decay. Radioactivity is measured in units termed Curies, defined as $3{\cdot}7 \times 10^{10}$ disintegrations per second. One watt corresponds to $3{\cdot}1 \times 10^{10}$ fissions per second, so that a reactor working at a power level of one watt contains at least $\frac{3{\cdot}1}{3{\cdot}7} \times 2 = 1{\cdot}7$ curies of radioactivity. Operation at the megawatt level is consequently associated with the production of millions of curies of radioactivity within the reactor.

In order to keep the neutron flux and gamma radiation in the vicinity down to a level that is safe for the operators, reactors have to be enclosed within concrete shields many feet thick. If the pile stops working the neutron flux disappears, but the radioactivity due to continuing fission product disintegration decays only gradually in accordance with the half-lives and relative amounts of the various fission elements formed.

After being withdrawn from the pile, the uranium charge must be left to "cool off" for a considerable period before processing for plutonium extraction can commence. About 70 per cent. of the gamma activity disappears within 100 days, but the remaining long-lived activity makes it necessary to carry out all processing by remote control from behind shields and presents a rather awkward problem of safe ultimate disposal.

Radioactivity is highly injurious to human beings, so that once produced it must thereafter be contained. Hazards are the escape of airborne or waterborne activity (in significant amounts) from chemical processing plants and the unlikely event of a pile getting out of control and producing enough heat to melt or vaporise its fuel elements, thus releasing a highly radioactive cloud comparable to that produced by the atomic bomb. It need hardly be said that the precautions taken to prevent any such occurrences are of quite exceptional rigour.

ROUTES TO NUCLEAR POWER.

Present production piles run at relatively low temperatures and the fission heat is wasted. The only route to nuclear power discernible at present is to build reactors that will run at higher temperatures and generate steam for power plants of conventional design. Possible reactor fuels are natural uranium with only 0·7 per cent. of fissile material and various enriched fuels containing a much greater percentage. The latter are hoarded and are much more expensive, pure fissile material being at least 100 times as costly as gold. The major elements of a nuclear power plant are a reactor, a heat exchanger in which the reactor coolant transfers its heat to water-steam, and a turbo-alternator. Steam temperatures and pressures will be lower than in normal power-station practice because the reactor coolant must be hotter than the steam and the reactor interior must be hotter than the coolant, and the properties of available materials make it impossible to run the reactor as hot as one would like. We have to decide first whether such schemes are technically feasible, and then whether they are worth-while from the standpoint of economics and national policy.

The technical feasibility of nuclear-electric power plants can be taken as established. At Harwell we have designed an improved type of natural uranium reactor enclosed in a pressure shell, the heat produced being transferred by a gas under pressure through a heat exchanger to a steam turbo-alternator. The designed output and overall thermal efficiency of this plant are satisfactory and it is now being built. If my guesses as to its life and cost prove correct then, assuming no by-product revenue, the cost of electricity generated at a very high load factor should be about 1*d.* per kWh.

American engineers have also made feasibility studies and seem to have concluded that nuclear electric power in the United States at present is uneconomic unless supported by revenue from the sale of plutonium for military purposes. This in turn has disadvantages because "a duel purpose plant would have to be designed principally as a plutonium production plant. The design of the plant would be maximised for plutonium production at the expense of power production, because there are definite design conflicts. In order to avoid excessive losses of the vital plutonium the fuel elements would have to be discharged long before their value as fuel had been exhausted."*

In a non-military economy, power is the only objective and by-product plutonium has a market only as a nuclear fuel. The aim is then to extract the greatest possible amount of energy from a given quantity of uranium, with the minimum of expensive preliminary and subsequent processing. The possibilities of natural Uranium power reactors are therefore of particular interest. In these the basic fuel is U235, contained in natural uranium to the extent of 7,000 grams per *tonne*, which is consumed at the rate of about 1·3 grams per megawatt-day of heat release. The total amount of energy that can be extracted from a *tonne* of uranium, however, is limited by the following factors. First, and least limiting, is the fact that as the fuel is consumed a point is eventually reached at which the amount of fissionable material remaining is less than the amount required for operation, and the reactor will no longer operate. The formation of plutonium in the fuel elements, at the rate of about 3 atoms of Pu for 4 atoms of U235 consumed, considerably retards the rate of fissile depletion. Second, and more serious, as the fuel is consumed "ashes" known as fission products are produced which inhibit normal operation of the reactor by capturing neutrons and eventually, unless removed by chemical processing, cause a shut-down. Third, metallic uranium fuel elements suffer structural damage as a result of the severe radiation. Two or more foreign atoms appear in place of each uranium atom fissioned, and finally the fuel elements begin to crack up.

These effects, especially the latter two, now require that metallic uranium fuel elements be discharged from the reactor after only a fraction of the uranium has been consumed. At this point the spent fuel can either be stored for possible future economic recovery, or it can be chemically processed at great expense to remove the harmful fission products and refabricated into sound elements. Observing these facts it seems wise to assume that not more than half the energy of the U235 can be economically extracted in a natural uranium power reactor.* This makes one *tonne* of natural uranium the equivalent of about 9,000 tons of coal, so that some 4,000 *tonnes* per annum would then be needed to replace the 36 million tons of coal now burnt in the national power stations.

At this point it is well to remember that uranium is not found in the United Kingdom, but must be obtained overseas, by purchase, from countries who may become less willing to sell as they learn to use it themselves. We may be unable to buy 4,000 *tonnes* every year, and in any case we should try to use it more efficiently since, in principle, all the U238 can be converted into Pu239 and burnt. The natural uranium power reactor is technically feasible and almost economic but it does not use anything like the full potentialities of uranium; it is therefore not the final answer to the long-term national problem of finding a substitute for coal.

Let us now consider the so-called breeder reactor. This starts from the idea that 2½ neutrons per fission, less one to carry on the chain reaction, leaves 1½ for plutonium production and losses. Can we not cut neutron wastage to a figure that will leave more than one neutron per fission for plutonium production and so produce more fissile material than is consumed? In a breeder reactor, fissile "fuel material" (U235, Pu 239 or U 233) must be mixed with a convertible "source material" (U 238 or Th 232) the atoms of which become fissile when they capture neutrons. There is also a blanket of source material surrounding the reactor which captures usefully the neutrons that otherwise would escape. The neutron balance of a hypothetical breeder reactor is given in Table II.

TABLE II.

Neutron Balance for Fission of One Fuel Atom in Breeder Reactor	
Fission captures by fuel atoms—to maintain chain reaction at constant level	1·0
Non-fission captures by fuel atoms	c
Fast fission captures by source atoms	f
Non-fission captures by source atoms forming new fissile atoms	$1 + g$
Neutron wastage—escape, capture in coolant, etc.	w

Let x and y be the number of neutrons released by fission of one fuel atom and one source atom respectively, then the f fast fission captures in source atoms will produce fy neutrons, so that the total neutron production per fission will be $x + fy$. Since neutron production and consumption must balance:

$$x + fy = 1 + c + f + 1 + g + w,$$

* George L. Weil, Joint Committee on Atomic Energy, *Atomic Power and Private Enterprise*, page 16. (U.S. Government Printing Office, December, 1952.)

* G. L. Weil, *loc. cit.*, page 64. J. R. Menke, "Nuclear Fission as a Source of Power," Cowles Commission Special Papers No. 1: 1947.

whence

$$g = (x-2) + f(y-1) - c - w \quad . \quad (1)$$

Now consider the material balance, i.e., the loss and gain of fissile material. The number of fuel atoms destroyed is $(1+c)$, while the number of new fissile atoms created is $1+g$. Clearly the net gain is :—

$$g - c = (x-2) + f(y-1) - 2c - w \quad (2)$$

and if this quantity is positive the reactor is a true breeder; if zero, then gains at least balance losses. Note, however, that x and y and to a large extent also c and f depend upon nuclear constants outside the control of the designer. Proof of the possibility of breeding was announced by the U.S.A.E.C. in June, 1953.

Breeding looks most promising in a fast fission reactor having no moderator and fuelled with material of high fissile content. In such a reactor, however, the critical size is small, so that the heat release per unit volume gets very large, and cooling problems become formidable. Gas cooling is totally inadequate, while water cannot be used because it would act as a moderator; we are therefore driven to awkward liquid-metal coolants such as sodium.

It may be thought that since the total amount of fissile material in a breeder reactor remains constant or increases, refuelling would be unnecessary. This unfortunately is not the case, since some of the fission products are heavy absorbers of neutrons, so the wastage w will increase with burning time. For this and other reasons only a fraction bM of the original fuel charge of M grammes can be fissioned before processing to remove fission products becomes necessary. The quantity b will be called the "burn up" fraction. The operating cycle is thus a burning period of T_1 days, during which bM grammes of fuel are fissioned, followed by a chemical processing period of T_2 days, during which the original fuel is purified and the newly formed fuel is extracted. The net gain of fissile material after refuelling the reactor is $(g'-c)b$M grammes per cycle, where g' is the gain corrected for losses in the chemical extraction plant, which must be small since large extraction losses would constitute an impermissible hazard. The number of breeding cycles N, each of duration (T_1+T_2) days, needed to create a surplus of new fissile material equal to the original investment of M grammes is given by $N(g'-c)b\text{M} = \text{M}$, so that the doubling time or total duration of the N cycles is :—

$$\tau = \frac{T_1 + T_2}{(g'-c)\,b} \text{ days.} \quad . \quad . \quad (3)$$

The value of the gain $(g'-c)$ is unlikely to be large and is largely outside the designer's control; to shorten the doubling time one must therefore attack T_1, T_2 and b. If b M grammes of fuel are fissioned in T_1 days and 1·08 grammes of fissions release one megawatt-day of heat, then the average heat rate of the reactor is $b\,\text{M} \times 10^6 \div 1{\cdot}08\ T_1$ watts. If the load factor—that is the ratio of average to maximum heat rate—is L, then the maximum heat rate is $\frac{1}{\text{L}}$ times greater. The difficulty of cooling the reactor is determined by the heat rate per unit volume (or per unit mass) of the fuel. The specific heat rate r in watts per gramme of fuel (a limiting factor in design) is :—

$$r = \frac{10^6\, b}{1{\cdot}08\, T_1 \text{L}}, \quad . \quad . \quad (4)$$

giving $T_1 = \dfrac{10^6\, b}{1{\cdot}08\, r\, \text{L}}$. Substituting this in (3) gives

$$\tau = \frac{1}{g'-c}\left(\frac{10^6}{1{\cdot}08\, r\, \text{L}} + \frac{T_2}{b}\right) \text{days.} \quad . \quad (5)$$

On present knowledge of permissible specific heat rates, r and burn-up fractions b, doubling times look rather long, so that the rate of production of new fuel for commissioning new reactors may be rather slow. This being so, it would seem that the shortest route to large-scale nuclear power is to build several natural uranium reactors which, while generating power, will produce plutonium at a rate greater than any breeder reactor, since none has to be fed back. When enough plutonium is available we commission the first breeder reactor (which by that time we may know how to build), but rely not on its breeding but merely being self-sustaining in fuel as long as it is fed with source material (U238 or Th232).

When sufficient self-sustaining reactors are in commission, the conversion and fission of some 12-15 *tonnes* of U238 per annum will supply as much heat as the 36 million tons of coal now burnt annually in our power stations. It is, however, clear that the time scale for this programme is a long one, set not only by the laws of nature but also by the laws of finance. The long time scale imposed is perhaps a blessing, since nuclear power on the national scale will leave for safe and permanent disposal each year radioactivity equal to that of several hundred atom bombs, and we must learn to deal with this problem before we create it. Fortunately, the volumes involved are not large, so that storage is a possibility.

Economics of Nuclear Power Schemes.

Let C_1, C_2, C_3, etc. = capital cost, in £ per kW installed, of various components of the plant.

a_1, a_2, a_3, etc. = fractional annual charges for interest and redemption attached to C_1, C_2, C_3, etc.

A_1, A_2, A_3, etc. = annual charges, in £ per kW installed, for other standing items of costs (e.g., rates).

f = cost of fuel consumed, pence per kWh generated, including handling and ash disposal.

m = cost of oil, stores, water, maintenance, etc., pence per kWh generated.

L = annual load factor

$$= \frac{\text{units generated per annum}}{8{,}760 \times \text{kW installed}}.$$

The units generated per annum

$$= 8{,}760\ \text{L} \,.\, \text{kW} \qquad \text{(kWh)}.$$

and standing charges

$$= \Sigma\,(a\,\text{C} + \text{A}) \,.\, \text{kW} \qquad (£)$$

$$= \frac{240\,\Sigma\,(a\,\text{C} + \text{A})}{8{,}760\ \text{L}} \text{ (pence per unit).}$$

Hence the total unit cost in pence per kWh is :—

$$\frac{\Sigma\,(a\,\text{C} + \text{A})}{36{\cdot}5\ \text{L}} + f + m. \quad . \quad . \quad (6)$$

This equation applies to both nuclear and coal-fired stations. Quantities relating to nuclear stations will be primed. Nuclear power will be as cheap or cheaper than coal power if :—

$$\frac{\Sigma\,(a'\,\text{C}' + \text{A}')}{36{\cdot}5\ \text{L}} + f' + m' < \frac{\Sigma\,(a\,\text{C} + \text{A})}{36{\cdot}5\ \text{L}} + f + m,$$

the comparison necessarily being made at the same load factor. It then follows that :—

$$\frac{\Sigma\,(a'\,\text{C}' + \text{A}')}{\Sigma\,(a\,\text{C} + \text{A})} < 1 + \frac{36{\cdot}5\ \text{L}}{\Sigma\,(a\,\text{C} + \text{A})} \times [(f - f') + (m - m')]. \quad (7)$$

Typical values for British coal-fired stations are :—

$$\text{C} = 65l.\ \text{per kW}\,;\ a = 0{\cdot}08\,;\ f = 0{\cdot}45\,;$$
$$\text{and } m = 0{\cdot}078.$$

Natural Uranium Reactors.—The A.E.C. price for uranium oxide is 3½ dols. per lb., or 2,900*l.* per ton. Natural uranium metal has been estimated* to cost between 10,000*l.* and 20,000*l.* per ton, containing 7,000 grammes of U235. If all of this U235 could be burnt (at the rate of 1·3 grammes per MW day), the heat output would be 5,400 MW days per ton. A safer assumption is that only half this amount of heat can be extracted before the fuel elements must be withdrawn. At 25 per cent. generation efficiency, these figures give :—

$$0{\cdot}074 < f' < 0{\cdot}296.$$

As regards m', maintenance costs in a nuclear station should be smaller but ash-disposal costs may be higher because of the radioactivity. Assume for simplicity that $m' = m$ and $\text{L} = 0{\cdot}85$, then the right-hand side of equation (7) becomes :—

$$1 + \frac{36{\cdot}5 \times 0{\cdot}85}{0{\cdot}08 \times 65}\left(0{\cdot}45 - \frac{0{\cdot}3}{0{\cdot}08}\right) = 1{\cdot}9 \text{ to } 3{\cdot}2.$$

This suggests that a natural uranium power plant can be economic at a cost of two to three times that of a conventional plant, provided that the rates of interest, redemption and maintenance are the same.

This estimate assumes that the spent uranium is simply stored after as much energy as possible has been extracted from it. Actually, the spent charge will contain plutonium, and if this has a military value its extraction and sale may yield a revenue additional to that from power sales. In a non-military economy, however, plutonium has value only as a reactor fuel. To compete on this basis with natural uranium, plutonium should cost not more than 10,000*l.* to 20,000*l.* for 7,000 grammes, or at most 3*l.* per gramme. In a natural uranium reactor, the plutonium produced is about three-quarters of the U235 consumed; since only part of the U235 is consumed when the uranium is withdrawn, the amount and value of plutonium in the spent charge is much less than the amount and value of fissile U235 in the virgin metal. The cost of processing a ton of spent uranium should therefore be much less than the cost of a ton of virgin uranium. Since the spent charge will be radioactive while plutonium is highly toxic, processing costs are unlikely to be low and it may be impossible to meet this requirement.

Breeder Reactors.—In the case of a breeder reactor, assuming feasibility, chemical processing is essential and there are two sets of costs, i.e., those pertaining to the reactor and power plant, and those pertaining to the chemical plant. For any given energy cost f' there will be a maximum permissible cost for reactor and power plant set by equation (7). The energy cost f' is set by the total working costs of the chemical processing plants and the attainable burn-up. The reactor has to be charged with M. grammes of fissile material, of which a fraction b is fissioned in each cycle, yielding, at 25 per cent. efficiency, $24{,}000\ b\,\text{M} \div 4 \times 1{\cdot}08$ kWh of electrical energy. At the end of the burning period the charge and the irradiated source material in the blanket are processed and a fresh charge of M grammes made up by addition of newly-created fissile material to the unburnt portion of the original charge.

If the total cost of processing and making up the fresh charge is £p M per cycle, then the cost of the energy generated will be $240\,p\,\text{M}$ pence for processing alone, so that :—

$$f' > \frac{4 \times 1{\cdot}08\, p}{100\, b} \text{ pence per kWh.} \quad . \quad (8)$$

Thus, for a burn-up of 5 per cent., processing and make-up costs will have to be kept down to 10*s.* per gramme if f' is not to exceed 0·45*d.* per kWh. A breeder reactor, if feasible, should be economical of material but there is no certainty that it will be able to compete on costs.

Nuclear power is a certainty and economic nuclear power a possibility, but cheap nuclear power seems unlikely.

This paper is published by permission of the Director, Atomic Energy Research Establishment, Harwell, but expresses only the personal opinions of the writer.

* Liljeblad, World Power Conference, 1950.

THE BRITISH INDUSTRIES FAIR.—Preparations for the British Industries Fair at Castle Bromwich, Birmingham, which is to be held from May 3 to 14, 1954, are now in hand. The Birmingham Chamber of Commerce, organisers of the Castle Bromwich section of the Fair, state that there is already an indication that all the available space will be booked. They are arranging to increase the number of advance copies of the catalogue for distribution overseas from 14,000 to 20,000.

EFFICIENT OPERATION OF CENTRAL-HEATING BOILERS.—The Railway Executive have prepared a simply-worded booklet dealing with the operation of central-heating boilers. It is intended that this booklet shall be the basis of stokers' demonstration courses, which are being arranged in order to ensure that central-heating plant is operated efficiently and economically. The booklet explains the theory of combustion and what happens in a fuel bed, and how combustion may be controlled. It concludes with sections on the duties of a boiler attendant, and gives procedure instructions when lighting up at the beginning and closing down at the end of a heating season.

STANDARD 2-6-2 TANK LOCOMOTIVE, BRITISH RAILWAYS.

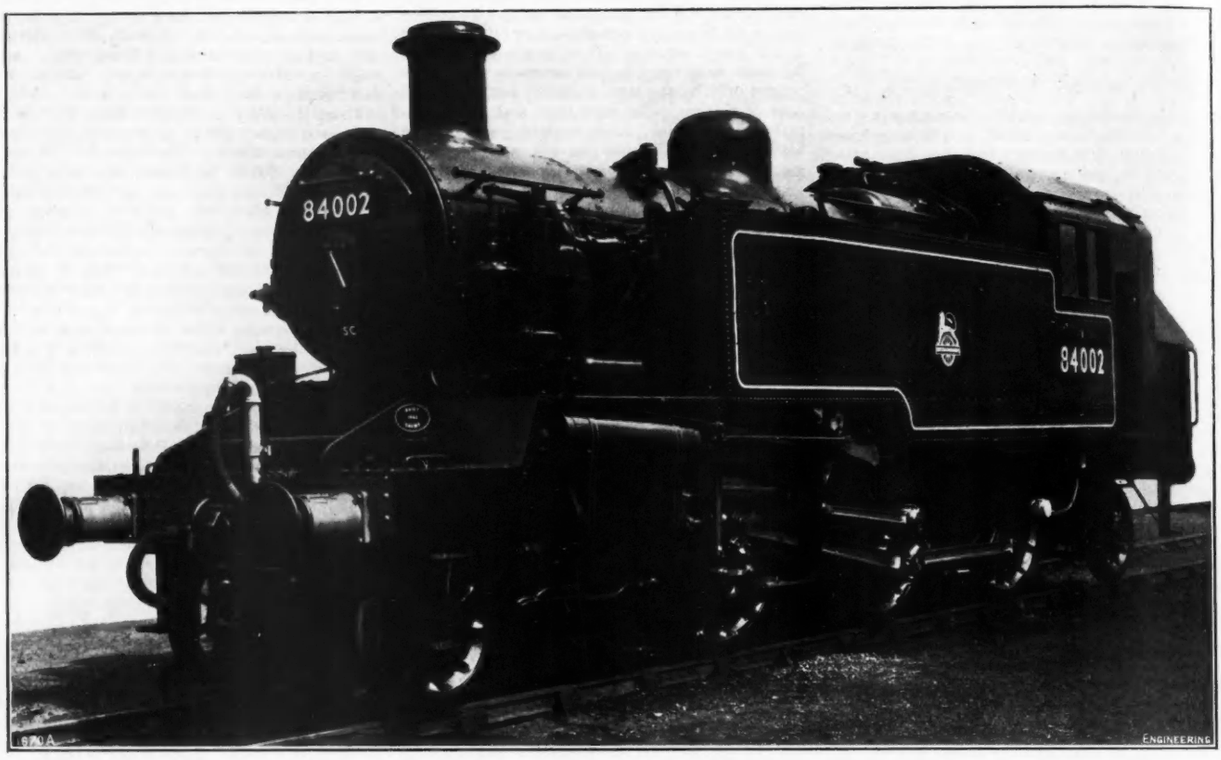
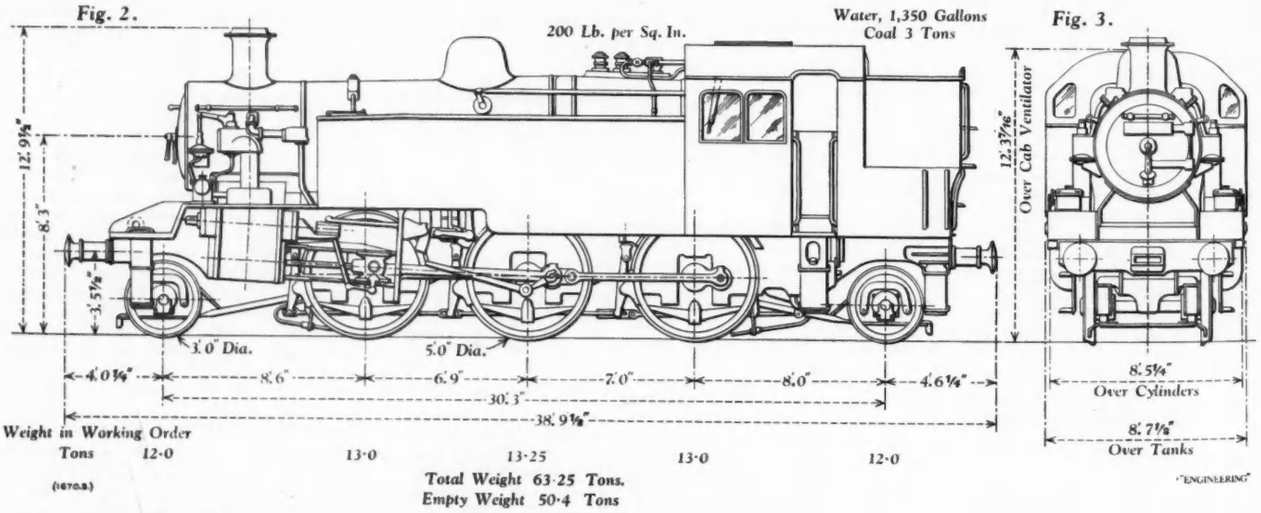


FIG. 1.



STANDARD 2-6-2 TANK LOCOMOTIVES, BRITISH RAILWAYS.

BRITISH Railways are now building, at Crewe Works, 20 locomotives the design of which is the ninth in the series of 12 standard designs.* These Class-2 2-6-2 mixed-traffic tank engines, one of which is shown in Fig. 1 above, are the smallest tank engines of the standard range. Many features of the design are common with those of the Class-2 2-6-0 tender locomotives which were built earlier this year. They include a rocking grate, self-emptying ashpan, self-cleaning smokebox, etc., all of which are intended to reduce the time required at the running shed and to give the maximum mileage between shop overhauls. S.K.F. self-aligning ball bearings are fitted to the return cranks but the axleboxes have plain bearings. Soft-grease lubrication is widely used.

The new engines are to work on the London Midland Region, on branch-line passenger services of the type at present handled by old 2-4-2 and 0-4-4T engines of pre-grouping design. The boiler pressure is 200 lb. per square inch; there are two outside cylinders, 16½ in. by 24 in.; the coupled wheels are 5 ft. in diameter; and the tractive effort is 18,513 lb. The engine weighs 50·4 tons empty and 63·15 tons in working order and its adhesion factor is 4·7. The axle-loads and the principal dimensions are given in Figs. 2 and 3. The locomotives are being designed and built under the direction of Mr. R. A. Riddles, C.B.E., M.I.Mech.E., member for mechanical and electrical engineering, Railway Executive. The parent office for the design is Derby, but component parts have also been designed at Swindon, Brighton and Doncaster. The 20 engines of the class will be numbered 84000 to 84019.

THE BOILER.

The boiler is interchangeable with that used on the standard Class-2, 2-6-0 tender engine, and is generally similar to that used on the Class-2, 2-6-0 and 2-6-2 engines of L.M.S. design. The barrel consists of two rings of carbon-steel plate,

* Articles on the first eight standard classes appeared in ENGINEERING as follows: 4-6-2 Class 7, vol. 171, pages 126 and 341 (1951); 4-6-0 Class 5, vol. 171, page 528 (1951); 4-6-0 Class 4, vol. 171, page 752 (1951); 2-6-4 Class 4 tank, vol. 172, page 138 (1951); 4-6-2 Class 6, vol. 173, page 108 (1952); 2-6-2 Class 3 tank, vol. 173, page 698 (1952); 2-6-0 Class 4, vol. 175, page 12 (1953); and 2-6-0 Class 2, vol. 175, page 217 (1953).

the second tapered equally at the top and bottom. The outside diameter increases from 4 ft. 3 in. at the front ring to 4 ft. 8 in. at the firebox end. The front ring is $\frac{1}{2}$ in. thick and the back ring $\frac{11}{16}$ in. thick, and a drumhead smokebox tubeplate is fitted. The barrel contains 12 flue tubes, $5\frac{1}{8}$ in. diameter outside and 7 s.w.g. thick, and 162 small tubes $1\frac{5}{8}$ in. diameter outside and 12 s.w.g. thick. The length between tubeplates is 10 ft. $10\frac{1}{2}$ in. and the superheater elements have an outside diameter of $1\frac{3}{4}$ in. The free flue area is 2·77 sq. ft.

The Belpaire firebox is 5 ft. 11 in. long and 4 ft. $0\frac{7}{16}$ in. wide outside, giving a grate area of 17·5 sq. ft. The steel outer wrapper is $\frac{11}{16}$ in. thick, and the copper inner-firebox wrapper is $\frac{7}{16}$ in. thick. The throatplate, $\frac{5}{8}$ in. thick, and the backplate, $\frac{11}{16}$ in. thick, are both vertical. All water-space stays are of Monel metal, nutted inside the firebox, but the roof, longitudinal and transverse stays are of steel. The heating surfaces are 924 sq. ft. for the tubes, 101 sq. ft. for the firebox and 134 sq. ft. for the superheater. Separate top-feed clack-valves are mounted on the front barrel at 30 deg. each side of the vertical centre-line, and discharging the delivery from two 8-mm. live-steam injectors on to a tray deflecting the water away from the tubes to the sides of the barrel. Both injectors are mounted on the right-hand (fireman's) side.

Frames, Cylinders and Motion.

The main frame plates are 1 in. thick and are held by fabricated stays. Hornblocks are provided for the driving axle and guides for the leading and trailing coupled axles; they are fitted with manganese-steel liners welded and riveted to mild-steel backplates, which are in turn bolted to the guides, thus permitting subsequent adjustment. The coupled axleboxes are of cast steel with pressed-in horseshoe brasses. Mechanical lubrication is fed direct to the underkeeps, in which a worsted pad feeds the oil to the journal. Manganese-steel liners are welded direct to the axlebox-guide surfaces.

The cylinders have 8-in. diameter piston valves operated by Walschaerts gear. This gives a travel of approximately 6 in. in full gear, with $1\frac{5}{16}$ in. lap and $\frac{1}{4}$ in. lead. Connecting-rod big-ends and coupling-rod bearings are fully whitemetalled, with oil distributed by felt pads over the bearings. The pads are splash-fed from integral oilboxes. The cylinders and valve chests are lubricated by a mechanical lubricator through atomisers working in conjunction with the cylinder cocks. The top slide-bars are also mechanically lubricated. All motion pins, except the expansion-link and radius-rod die pins, dies and die paths, are soft-grease lubricated; the exceptions are oil-fed.

The leading pony truck has double helical springs for lateral control. Two spring-loaded friction dampers fore and aft of the truck centre also control the side movements. Coil springs are used, at each end of a yoke, to transmit the weight to the axleboxes, which are of bronze. The trailing truck is of the swing-link type and is fitted with similar friction dampers. The swing links are of the three-pin type. The minimum radius of curvature that the engine can negotiate (with specified gauge-widening) is 4 chains.

Brakes and Vacuum-Controlled Regulator.

The steam and vacuum brake equipment is identical with that used on other B.R. standard steam locomotives, consisting of twin "SSJ" ejectors alongside the smokebox, in conjunction with a horizontal-acting vacuum-brake valve and graduable steam-brake valve. The vacuum-brake control automatically gives a graduated steam-brake application on the engine, and the steam brake can be applied independently if desired. The braking force is 48 per cent.

To enable these engines to work "push-and-pull" trains under the control of the driver at the other end of the train, vacuum-controlled auxiliary regulator valves are fitted in each steam pipe from the superheater header to the cylinders. These are single-seated poppet valves, mechanically operated by linkage from a diaphragm-type vacuum cylinder. The driver can operate these valves from the compartment at the opposite end of the train, by a supplementary train pipe and vacuum controls.

SIGNAL-SPECTACLE GLAZING.

The replacement of broken spectacle glasses in signals, which have been secured in the first place by means of putty and bifurcated rivets, is a slow and laborious process, since it involves the complete removal of the age-hardened putty before a new glass can be fitted into a signal-arm spectacle. Moreover, the work has to be carried out from the signal ladder, in all sorts of weather and, not infrequently, during the hours of darkness.

A new method of fitting these glasses to signal-arm spectacles has recently been devised and introduced on the London Midland Region of British Railways. Fig. 1 shows a new glass being fitted by hand, using a removable metal ring which temporarily deforms a rubber ring of S-section. The rubber ring is shown in Fig. 2. The method

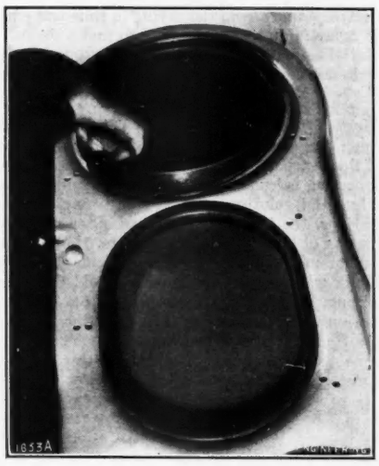
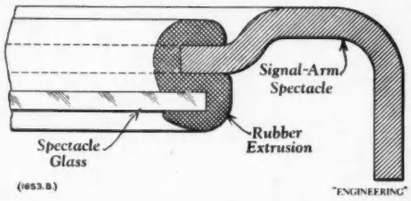


Fig. 1.

Fig. 2.



of fitting the glass and the rubber ring is simple. The rubber ring is first stretched over the rim of the spectacle glass to be fitted, which is then held by the lower leg of the ring; the upper leg is then turned inwards and compressed, or contained, by a removable metal ring. The metal ring is then inserted in the signal-arm spectacle from the back, and then pulled free, when the upper leg takes up its pre-formed position, turning outwards and gripping the signal-arm spectacle. Apart from ease of fitting, the method has the advantage of providing insulation against vibration, and a watertight joint.

Refresher Course for Works and Plant Engineers.—A course of lectures intended for works and plant engineers will be delivered at Brasenose College, Oxford, from Monday, September 21, to Friday, September 25, 1953. The lectures will be followed by discussions and the syllabus will include the economics of fuel selection, combustion control in practice, steam generation, the determination and interpretation of heat balances, compressed-air appliances and practices, the control of power factors and maximum demand, waste-heat recovery, and the design, performance and operation of power plant. There will be a visit to the Morris Motor Works at Cowley. The fee for the course will be 2*l.* 10*s.* and accommodation will be obtainable at an additional charge of 4*l.* Applications should be made to the secretary, Fuel Education Joint Advisory Committee, Southern Region, Ministry of Fuel and Power, Whiteknights, Earley, Reading.

THE UTILISATION OF ELECTRONIC DIGITAL COMPUTERS IN ENGINEERING PRACTICE.*

By R. K. Livesley.†

It is hoped that the reader is acquainted with the general principles on which automatic digital computers are based. While it is not intended to describe any machine in detail here, it may be convenient to summarise these principles, in order to define some of the technical terms used later in the paper.

A digital computer consists essentially of a high-speed store and an arithmetic unit. The store generally has a capacity of between 100 and 1,000 numbers, each with about 10 decimal digits, and the arithmetic unit performs operations on these numbers at a rate of about 1,000 per second. These arithmetic operations (addition, multiplication, transfer, etc.), are performed in sequence under the control of a "routine," or list of coded instructions, each instruction corresponding to one operation. The routine determining the operation of the machine at any instant is normally kept in some part of the high-speed store. In order to carry out a given calculation, the relevant routine and the numerical data must first be fed into the machine, the usual medium being either punched cards or teleprinter tape. Results are either recorded in the same way, or typed out for immediate visual inspection. Some computers, such as the Manchester machine, have also a subsidiary store of large capacity, where numerical information and routines may be kept while not actually in use. This store is normally a magnetic drum or disc, although ordinary recording tape has also been used.

Thus a digital computer will carry out any calculation which can be performed on a desk calculating machine, provided that it is first supplied with a detailed account of the operations required. In this respect it closely resembles a human slave, who will only do what he is told, but will do it extremely quickly and accurately. The collection of routines for carrying out a given computation is known as a "programme," and the task of making up these routines and assembling them in their correct order is called "programming." Most computing machine organisations spend a considerable part of their first few years of existence in building up a library of basic routines. These cover the standard processes which occur in almost all computations, such as the generation of elementary functions, the solution of sets of linear algebraic and differential equations, the inversion of matrices, etc. Routines for the input of instructions and numerical data, and for the printing of results, are also developed during this period. Once such a library has been built up, the programmer will find that many of the routines he requires are already available, and that all he has to do is to connect them in a suitable order.

Classification of Engineering Problems.

When considering whether to programme a given calculation for a digital computer it is important to distinguish between single and repetitive problems. In the first class the results, once obtained, form the complete answer to the problem, and the programme is then of no further use. Many calculations in physics and pure mathematics are of this type. In view of the time required for the development of routines, there is a definite lower limit to the size of problem for which automatic computation is economic. If a non-repetitive calculation would take more than four weeks to complete with the aid of a desk machine, it is probably worth programming, but smaller problems are best done by hand.

Most engineering problems, however, are repetitive, in the sense that the same calculations are repeated for various sets of initial data. Each separate calculation may not be particularly irksome on a desk machine, but the sum total imposes a

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* Paper read before Section G of the British Association at Liverpool, on Thursday, September 3, 1953.

† Manchester University Computing Machine Laboratory.

monotonous and unprofitable task on the engineer or his assistant. In such a case the value of a digital computer is evident, since a single programme, once developed, may be used to solve an indefinite number of separate problems. In these circumstances it is worth-while spending time on programme development, in the same way as one would spend time on the development of any machine tool for continuous production. In particular, it may be desirable to increase the complexity of a programme, if by adding a few dozen extra instructions one can extend the range of data covered, simplify its preparation, or increase the speed or accuracy of the computation.

An obvious application of these principles is to problems of engineering design. In simple problems of a geometrical nature it may be possible to develop programmes which, given the basic generating data, produce the detailed dimensions required for manufacturing drawings; the development of turbine-blade profiles might be feasible on these lines. In more complicated problems, although it would not usually be possible to make the design process fully automatic, programmes for rapidly checking trial layouts would certainly be very useful. For instance, in designing a mechanical part to withstand a given load, it is usually necessary to investigate a number of designs, using some condition, such as minimum weight, to choose between those which satisfy certain stress conditions. A stress-analysis programme would enable the engineer to discover the effect of altering the various parameters of his design with little effort, each trial only requiring the preparation of a short data tape or punched card. It may be mentioned here that with a well-designed programme it is no more difficult to prepare a data tape than it is to type out the relevant information in the usual way.

Typical Problems.

In order to show more clearly the way in which these general ideas may be applied to specific problems, we shall consider four of the programmes of engineering interest which have been developed for use on the Manchester computer.

(*a*) Determination of the natural frequencies and associated normal modes of shaft systems in torsional oscillation. It is assumed that the system can be idealised as a set of heavy discs connected by uniform light cylindrical shafts.

Capacity.—Up to 31 degrees of freedom (i.e., 32 discs).

Input data (Idealised system).—Dimensions of interconnecting shafts and their modulus of rigidity; moments of inertia of discs.

Time of Calculation.—Half to two minutes for each mode, according to the number of degrees of freedom.

(*b*) Determination of the critical speeds of turbine shafts rotating in three or more bearings. As in (*a*) above, the system is replaced by an idealised one of concentrated weights and light shafts. Any degree of flexibility in the bearings may be allowed for, and their number and position varied. The effect of a temperature gradient along the shaft may also be included.

Capacity.—For practical purposes, unlimited.

Input Data (Idealised system).—Weights; lengths and moments of inertia of shaft sections; bearing details.

Time of Calculation.—The four lowest critical speeds calculated in 30 minutes to 1 hour, according to the number of degrees of freedom.

(*c*) Calculation of the profiles of two cams, used for the measurement of the mass and energy of gas flow. The radius vectors are calculated at prescribed angular intervals.

Input Data.—Initial and final gas pressures; angular interval required.

Time of Calculation.—15 seconds to calculate and print each pair of radius vectors.

(*d*) Structural analysis of rigid-jointed plane frameworks under given loading.* It is assumed that all members are straight and uniform, and that all loads are applied at the joints.

Capacity.—Frameworks with up to 10 joints (i.e., up to 30 degrees of freedom) in a single calculation, or frameworks of any size by a process of successive reduction. Individual members with any practical dimensions—i.e. all standard and built-up steel sections.

Input Data.—Member details (length, moment of inertia, etc.), for formation of member stiffnesses; geometrical connection of members in framework; applied load system.

Output.—Displacements and rotations of all joints. Internal forces acting on each member, i.e., direct force, shear force, and bending moment, at each end.

Time of Calculation.—A power-station framework with 16 joints and 25 members was completely analysed in 17 minutes, including printing results. The data tape took 3 hours to prepare.

In these and other programmes developed on the Manchester computer the overall machine speed is about 150 times that of hand computation, this factor tending to be higher on large problems than on small. Apart from the saving in time and effort, this figure is quite high enough to make the use of a digital computer a sound economic proposition for a wide range of problems.

Mathematical Aspect.

Most of the problems described in the previous section are essentially problems in linear algebra, and this is true of a large number of other standard engineering calculations. The fundamental process is thus the solution of a set of linear algebraic equations, the inversion of a matrix, or the determination of latent roots and vectors. Many of the common methods for solving particular problems on desk machines are designed to avoid the formal manipulation of large matrices or sets of linear equations. With an electronic computer, however, these linear algebraic processes are very fast and simple to programme. The Manchester machine, for instance, will solve a set of 30 linear equations in 2½ to 4 minutes, and invert a matrix of similar size in 7 to 12 minutes. Thus many problems are best treated by a formal matrix approach, such methods often having the advantage of great flexibility of application, and being easy to programme, since routines will be already available for the formal matrix operations.

It is, however, a great mistake to use a digital computer merely for these formal matrix computations. If it can do the difficult job of inverting a matrix it can obviously perform the much easier one of setting it up from the original drawing-board data. Apart from the saving in hand calculation, the initial data are usually much more concentrated, and consequently less liable to error. Thus in analysing a structure with 10 joints by programme (*d*), described above, the machine sets up and solves the set of 30 linear equations connecting the joint loads and the joint displacements. The 900 coefficients in these equations are all functions of the dimensions and geometrical arrangement of the framework, which can usually be specified by about 50 numbers. It is clearly preferable to feed in 50 numbers directly from a designer's layout, rather than to calculate all 900 coefficients by hand, and then have to punch them out for input to the computer.

In general, matrix operations should take place entirely within the machine, the initial data and the final results being the physically meaningful quantities with which the engineer is accustomed to deal. If the programmer realises that formal matrix algebra is only part of any calculation, and sees his task as the creation of a programme running right from the initial physical data to the final results, a programme using matrix algebra may be used by any engineer, even if he is quite ignorant of such methods.

The Human Aspect.

At the present time there are very few people with programming experience, and of these only a few are concerned with engineering problems. The engineer wishing to solve a problem on a digital computer is thus normally faced with the task of programming it himself. It may therefore be of interest to give a rough guide to the time required to complete an average programme. Learning to programme is like learning a new language, and the time taken generally varies from three weeks to three months, these figures applying to a person with a good scientific training but no previous experience of digital computers. Although some knowledge of numerical methods is desirable, an honours degree in mathematics is by no means essential, unless the programmer is working on problems which are in themselves mathematically complex.

As the programmer becomes more experienced, the time taken both to make a programme for a given calculation and to perfect its operation on the machine will decrease considerably. Programmes nearly always contain errors when first written down on paper, and it is the elimination of these which takes up most of the development time. A proficient programmer will usually take from three to six weeks to develop a programme for a calculation of average complexity, once the numerical method has been chosen. This period covers the development of a prototype programme up to the point where the first correct answers are produced. Further development work, in which the prototype is transformed into the final production model, is a process of refinement of detail, as with any other engineering product. At this stage attention is focused on streamlining the input and output of data and results, and increasing the speed and flexibility of the programme. Small improvements may be made continuously as the result of operating experience, the degree of refinement depending on the frequency with which the programme is used.

It must be emphasised that the efficient use of an automatic computer depends entirely on the skill of the programmer. To assign low-grade personnel to the task of programming is always false economy. Both training and programme development times are greatly increased, and the final programmes are usually inefficient and awkward to use. If a problem has already been programmed, however, it may be handed over to unskilled assistants, who will merely have to punch out the data and feed it into the machine.

Conclusion.—The use of digital computers for doing automatically what has previously been done by hand is only a part of their application to engineering problems. In the first place, the speed and accuracy of such machines mean that more laborious calculations can be undertaken than would be feasible by human computers. Thus accurate answers to problems at present solved by rule-of-thumb methods may be obtained. In the second place, the use of a single programme for the analysis of a number of trial designs enables a final design to be reached in a far shorter time, while permitting a considerable increase in the number of systems analysed.

It has been mentioned that matrix methods have proved very useful in connection with linear problems. There is considerable scope for research into the development of new methods of numerical analysis especially suited to digital computers. In particular, the ease with which one may analyse a given system suggests the possibility of mechanising a complete design process. At first sight it only appears necessary to make the analysis programme part of a larger programme, this larger programme altering the design parameters between each analysis until a design is found with mimimal properties—usually of cost or weight. But the problem has now been transformed into one of inequalities rather than equations, and poses serious mathematical difficulties of convergence and uniqueness of solution, as well as of method. Many of the alterations which a designer makes are the result of intuition and experience rather than mathematics, and to programme such intuition and experience is clearly very difficult. Little work has so far been done on design programmes of this type, but they offer interesting research possibilities.

The author wishes to thank the Research Department of the Metropolitan-Vickers Electrical Company for permission to describe two programmes (Examples (*b*) and (*c*)) developed by members of their staff working on the Manchester computer.

* This programme is described in more detail in an article which appeared in ENGINEERING on pages 230 and 277 of the issues for August 21 and 28, 1953, respectively.

Exhibition of Architecture and Building, Australia.—This exhibition, arranged by the Royal Australian Institute of Architects, 16, Barrack-street, Sydney, will be held in Sydney from May 3 to May 28, 1954.

AUTOMATIC COMPUTING IN AIRCRAFT ENGINEERING.*†

By G. G. ALWAY, B.A.

THE design of any large piece of engineering equipment often requires much computing. There are so many design parameters involved that, to make sure the equipment or any part of it will work in the intended fashion, it is necessary to calculate the performance for many values of the parameters and so obtain a reasonable design. Good computational work can thus save money on experiments. The more complex the equipment, the more necessary is it that sufficient calculations should be done at an early stage so that costly delays in production do not arise due to alterations in design. This is most relevant to the design of aircraft.

Computing Machines.—In the past, the power of computing methods and the importance of using the best available has not been widely realised and inefficient methods have often been used. Because of the large amount of work involved, for many computing problems mechanisation has become a necessity and the engineer has naturally turned to analogue devices which either simulate the behaviour of the system under investigation or, like the differential analysers, can be made to obey the same differential equation as the system. These machines have a limited accuracy, but they are adequate for many problems and are easy to use.

Now that more automatic digital computers are being completed they are being brought to bear on engineering design problems. The scope of these machines is much wider than that of analogue machines, but they require a more elaborate organisation to use them. Programmers have to be trained. The programming for a digital computer may be considered as equivalent to the building of an analogue simulator for a particular problem. Such a simulator can only deal with the problem for which it was made. Where a numerical method is adequate for obtaining the solution to a problem, this can be programmed and used on a digital machine and the work may be carried out to any number of figures. The complexity of the problems which may be dealt with by automatic digital machines is limited only by the size of the store. With the advent of these machines more complex calculations, in which fewer approximations are made, can be attempted and completed in practical times.

The digital machine at the National Physical Laboratory, the pilot A.C.E., has been in operation on a variety of problems for 18 months and during this time a considerable library of programmes has been built up. It has only a limited high-speed store (it is hoped shortly to add a magnetic-drum auxiliary store) but the use of Hollerith punched cards as an auxiliary store has proved very successful. Although the reading and punching of cards is much slower than operations on the numbers in the high-speed store, the use of cards in this way does not mean that the machine is used in such an inefficient manner as one might think. Certain features of the logical design of the machine enable calculations to be done while the cards are being read or punched, and some problems can be organised so that the machine achieves up to 80 per cent. of the speed which would be possible if all numbers were in the high-speed store.

The pilot A.C.E. has perhaps been more successful in dealing with problems concerned with matrix algebra than in any other field. Programmes for solving sets of simultaneous linear equations have been made, using the auxiliary card store as described above. At present, the programmes will deal with sets for which the sum of the number of unknown variables and the number of right-hand sides is less than 192. By using columns of the unit matrix as right-hand sides we can thus invert a matrix of order 95, using this programme.

Programmes for finding latent roots and vectors of a matrix have been made, based on iterative methods. The simplest method one can use is to form a sequence of vectors, each of which is formed from the previous one by multiplication by the matrix and a normalising factor, the latter being necessary in order to prevent the numbers arising from growing out of range. This sequence of vectors tends to the latent vector corresponding to the largest latent root of the matrix, and the speed of convergence depends on the separation of this largest root from the next largest. If the cards are not used as an auxiliary store, a symmetric matrix of order 19 or an unsymmetric one of order 15 can be dealt with in this way. The largest root can be removed from the matrix and the next largest formed by a similar procedure, and so on. For matrices of higher orders, cards are used as an auxiliary store to hold the elements of the matrix. The matrix is read from the cards into the machine, once for each iteration. This method has been used successfully on a matrix of order 92.

For finding complex latent roots a similar iterative procedure has been used, in which the sequence of vectors is formed by multiplying by the matrix plus a purely imaginary multiple of the unit matrix. Without use of cards, matrices of order 10 can be dealt with and, using the cards, a programme has been made which can deal with orders up to 32. All these programmes are in constant use. Many applications have been to problems required by aircraft firms.

Typical Problem.—One problem of aerodynamic design to which automatic digital computers will be able to contribute is the flutter problem. Briefly, the couple and lift on an aeroplane wing depend on the angle of incidence of the airflow, and when this alters they do not alter immediately, but lag behind. Thus it is possible to have conditions in which, when the wing is vibrating, these forces will reinforce the elastic forces in the wing and cause the oscillations to build up and structural damage to ensue. The aeroplane must be designed so that this will not happen at any speed at which it is designed to fly. The differential equations representing the complete motion of the whole aircraft as an elastic body subject to aerodynamic forces are intractable, but experienced design engineers are able to tell when certain modes of vibration will be important for the problem of flutter.

In the first place, the modes of vibration of the aeroplane *in vacuo*, i.e. without the aerodynamic forces, are usually obtained. This involves finding the latent roots and vectors of a matrix. For the complete flutter problem the equations can be set up for a limited number of degrees of freedom and for sinusoidal motion only. This in itself involves no small amount of computing, most of which can be reduced to matrix multiplication, which is eminently suitable to a high-speed computer. The solution of these equations will then give the motion at the speed of the aircraft when the oscillations are critically stable, and so the boundary of the flutter region can be determined. This solution is, in general, required for a range of values of parameters and involves finding the values of velocity and frequency which make a determinant zero. The elements of this determinant are complex and depend on the velocity and frequency. They are of the form $a\omega^2 + ib\omega + c + \frac{e}{V^2} + id$, where ω is the frequency parameter, V the velocity, and a, b and c depend to some extent on ω.

Using hand computing, one would not usually attempt to consider more than four degrees of freedom, which would make this determinant of order 4. Thus some modes of vibration have to be ignored and the whole problem treated in an approximate fashion. Various analogue simulators have been made for solving the problem, taking into account six degrees of freedom, and these are used extensively. Nowadays, when new wing shapes are being designed and higher speeds are possible where the aerodynamic forces are not known with any certainty, this problem is increasingly important.

For the pilot A.C.E., two programmes for this particular part of the flutter problem have so far been made. One for the case when d is zero (calculation of complex determinants can be avoided in this case) and the determinant is of order n, less than or equal to five. The a, b, c and e and a value of V are fed into the machine and stored, and the determinant is expanded as a polynomial in ω. The real and imaginary parts of this polynomial are equated to zero and ω eliminated, giving a single number which has to be made zero by varying V. All this involves the calculation of 3^n real determinants. These are punched out on cards and fed into the machine again, to be summed in the appropriate way to form the coefficients of the polynomial in ω, and the eliminant is calculated from these coefficients. The whole process takes less than five minutes for the calculation of a single eliminant when $n = 5$.

Another programme which evaluates complex determinants has been made. This does not involve the use of cards as an auxiliary store and can deal with order n less than or equal to 8. The computation time for a single determinant of order 8 is a quarter of a minute. In using this programme a set of values for the frequency and the velocity are chosen and the flutter determinant evaluated for each pair of values. Inverse interpolation then gives the required values of the velocity and frequency which make the determinant zero.

In conclusion, it must be emphasised that, unlike analogue simulators, automatic digital computers become more powerful the more they are used. In the first place, a library of sub-routines is built up which facilitates the programming of new problems; and, in the second place, programmers continually improve the techniques for using their machine. Not only are better methods of solving particular programming problems worked out, but the most convenient way of arranging for the machine to read in and punch out data is found.

The work described above has been carried out as part of the research programme of the National Physical Laboratory and this paper is published by permission of the Director of the Laboratory.

* Paper read before Section G of the British Association at Liverpool, on Thursday, September 3, 1953.

† Communication from the National Physical Laboratory.

NOTES ON NEW BOOKS.

Précis de Mécanique des Fluides à l'Usage des Ingénieurs.

By PROFESSOR M. SÉDILLE. Dunod, 92, Rue Bonaparte, Paris (6e). [Price 780 francs.]

ENGINEERS, to whom this book is addressed, might well be tempted, on reading the announcement on the wrapper that it provides a "survey of fluid mechanics in 154 [actually 133] pages and without mathematics," to dismiss it as a popular work for the general reader. This, however, would be a mistake, for, though mathematics are not shunned altogether, they are used sparingly and further curtailed by confining the analysis, wherever possible, to two-dimensional motions. This economy in symbolism helps to disengage the underlying principles more clearly, while the extension to three dimensions is not usually difficult to carry out, once the essential ideas are securely grasped. Ideal fluids are treated first, their general equations of motion derived, and irrotational and rotational motions and conformal representation briefly considered. A short account of the argument from dimensions is followed by a general introduction to the properties of real fluids. Under laminar motions, the Navier-Stokes equations for the motion of viscous fluids are deduced, Poiseuille's equation for viscous flow through tubes is obtained and the theory of the boundary layer discussed at some length. In the account of turbulent motion, particular attention is paid to the probability distribution of velocity fluctuations, energy dissipation, turbulent motion in pipes and to the boundary layer in turbulent flow passed smooth plane surfaces. Following a short discussion on the effects of surface irregularities is a chapter on the resistance experienced by bodies of various shapes in their passage through fluids, and the nature of the wake left behind them. Selected examples of important practical situations in which the equations applicable to inviscid fluids are capable of yielding results in substantial accord with experimental findings are then considered, after which comes a chapter on compressible fluids,

including a general account of shock waves, and a final chapter devoted to heat exchanges in fluids. The author's experience in the dual rôle of technical director of the Rateau organisation and of professor at the École Centrale is happily combined in this concise outline of the present position in fluid mechanics.

Tables of Chebyshev Polynomials $S_n(x)$ and $C_n(x)$.

United States National Bureau of Standards Applied Mathematics, Series 9. The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 1·75 dols.]

THE Chebyshev polynomials of the first and second kind are defined, respectively, by the relations $T_n(x) = \cos(n \arccos x)$, $U_{n-1}(x) = \frac{\sin(n \arccos x)}{\sqrt{1-x^2}}$, so that their numerical values can be obtained with the aid of ordinary trigonometrical tables. The interest and importance of these functions is such, however, that a separate tabulation of them will be generally welcomed. This was suggested by J. C. P. Miller, who, besides contributing a foreword to this volume, also pointed out the advantages of tabulating the closely related functions $C_n(x) = 2\,T_n\left(\frac{x}{2}\right)$, $S_n(x) = U_n\left(\frac{x}{2}\right)$ as is done in the present table.

The coefficients of these latter polynomials, whose amplitudes oscillate between ± 2 instead of between ± 1, are still integers, but greatly reduced in size, as is apparent from Tables 1 and 2, which give explicit expressions for the first twelve C_n and S_n polynomials alongside the corresponding expressions for the T_n and U_n polynomials. Conversion from the former to the latter simply involves doubling the argument in each case and halving the C_n tabular entry. Tabulation is for values of x at intervals of 0·001 from 0 to 2. The tables are exact for the polynomials of degree $n = 2$, 3 and 4, while from $n = 4$ to $n = 12$, twelve decimal places are given. The particular interest of the T polynomials for approximation problems lies in the fact that expansion of an analytic function in terms of these polynomials produces faster convergence than expansion in terms of any other set of polynomials. An important application of this "economisation" of a power series is to curve fitting and is particularly valuable for the adjustment of empirical data, as the result is automatically the best in the least squares sense. These matters are fully discussed in the excellent introduction by Cornelius Lanczos, which also deals with the analytical, algebraic and arithmetical properties of the Chebyshev polynomials, functional equations, the solution of linear differential equations with rational coefficients by Chebyshev polynomials (the so-called τ-method), and includes a note on interpolation.

Radio Engineering, Vol. II.

By DR. E. K. SANDEMAN. Second edition. Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 55*s.*]

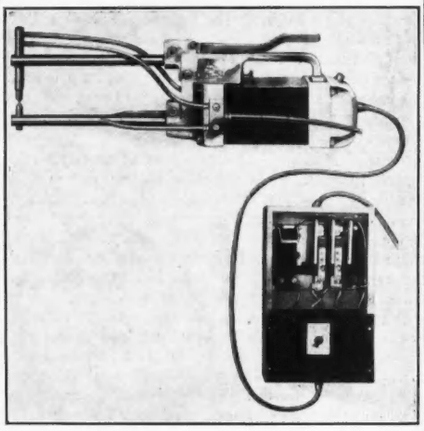
THE two volumes of Dr. Sandeman's *Radio Engineering* were reviewed at some length on page 665 of our 168th volume (1949). In the present edition of Vol. II, the section on the noise factor of a receiver has been extended to six pages instead of the former two, and a new section, of 29 pages, on transmission-line filters, has been included. Apart from these, the revision has been confined to occasional paragraphs, and—possibly by reason of the practical difficulties attending any extensive modifications to the text of a book of more than 600 pages—certain deficiencies to which we drew attention still remain. It would appear preferable, in the circumstances, to have issued the volume as a reprint of the original until such time as a more detailed revision was felt to be justified.

COAL PRODUCTION IN 1953.—Saleable coal mined in Britain during the 34 weeks ended August 29, 1953, amounted to 142,980,300 tons, compared with 145,145,100 tons obtained during the corresponding 34 weeks of last year, a decline of 2,164,800 tons.

PORTABLE SPOT-WELDERS.

A SPOT-WELDER which can be plugged into the ordinary mains supply, and then used where required, has obvious advantages over stationary machines, particularly for welding large or bulky workpieces. Ring Motors, Limited, Ayres-road, Old Trafford, Manchester, 16, have added a heavy-duty model to their range of "Leopard" portable spot-welders. The two earlier models are the "Universal," which has a current intensity of 6,000 amperes and weighs 26¼ lb., and the "Auto-Spot," giving a current of 4,800 amperes and weighing only 22 lb. This is for use on smaller work. A current of less than 20 amperes is drawn from the 230-volt mains to operate it.

The heavy-duty model S70-C/T, now added, is shown herewith, and is capable of most fabrication work in sheet metal. The illustration shows it fitted with water-cooled electrodes, but plain



ones are available for use where there is no convenient water supply, or when the electrodes have time to cool between operations. Various forms of tongs can be supplied to suit different types of work and can easily be interchanged. Pressure between the electrodes is applied by the handle on the top of the main body, operating through a toggle action; 600 lb. can be exerted with tongs 6 in. long. This model gives a current intensity of 8,500 amperes at 2·3 volts; if it is used on a 230-volt supply, a 60-ampere fuse is required. The transformer is damp-proof and built to conform with British Standard 638-1941. The illustration also shows the contactor-box and, with it, an automatic timer which can be supplied as an extra. This timer is useful in repetition work and can be set between 0·1 and 2·0 seconds. When joining 12-s.w.g. sheets together, 400 welds per hour can be made; the rate is increased to 2,000 when 22-s.w.g. sheets are being welded. The dimensions of the welder are 14¾ in. by 7 in. by 5 in.

COBB MEMORIAL, LOCH NESS.—A memorial to the late Mr. John Cobb, who was killed on Loch Ness on September 29, last year, while attempting to regain the world water-speed record for Britain, is to be unveiled on the anniversary of his death. It takes the form of a cairn erected on a hill overlooking the part of the loch where the speedboat, Crusader, disintegrated after travelling over the measured mile at a speed exceeding 200 m.p.h.

ELECTRICITY SUPPLY STATISTICS.—During July, 1953, 4,050 million kWh were sold by the British Electricity Authority to the Area Boards, an increase of 8·5 per cent. over the output in the same month of last year. When corrected for the weather and the number of working days, the increase was, however, 6·6 per cent., the weather having been much colder and there having been fewer effective working days than in July, 1952. The amount of electricity sent out by the Area Boards was also 8·5 per cent. more than in the corresponding month of the previous year. Supplies to "mainly industrial" areas increased by 6·7 per cent., and to "mainly non-industrial" areas by 10·5 per cent.

ANNUALS AND REFERENCE BOOKS.

Pipefitters' Handbook.

By FORREST R. LINDSEY. The Industrial Press, 148, Lafayette-street, New York 13, U.S.A. [Price 6 dols.]; and Bailey Brothers and Swinfen Limited, 26, Hatton-garden, E.C.1. [Price 51*s.*]

THIS handbook is intended primarily for those concerned with the laying and installation of pipes, but it would also be useful in estimating the lengths of pipe required for a job. The dimensions of pipe fittings are given for American standards and do not necessarily apply in this country. Many of the tables are of general use, however. Tables are given for finding the lengths of bends with radii up to 72 in. and angles up to 180 deg. Lengths and laying measurements are also given for offset bends, both for single pipes and for several pipes equally spaced. Other bends mentioned are for cross-overs and expansion allowances. There is a section on mitre joints and on the construction of templates for joining pipes of different sizes. The following 125 pages give laying lengths and dimensions for American standard pipes and fittings, and the volume ends with some general data and mathematical tables.

Colliery Year Book and Coal Trades Directory, 1953.

Thirty-fifth edition. The Louis Cassier Company Limited, Dorset House, Stamford-street, London, S.E.1. [Price 30*s.* net.]

THE contents of the new, 1953, edition of the *Colliery Year Book* and their arrangement follow the general pattern of recent editions, but additional data regarding opencast mining and a new section dealing with the collieries of Western Europe have been included in the present issue. As has been the case with previous editions, the statistical section, which includes data regarding United Kingdom and world coal resources, production, consumption, exports, costs and prices has been revised. The Directory portions of the volume include an official section covering Government departments, and associations, technical institutions and trade unions concerned with, or interested in, coal mining in all its forms; a National Coal Board section with lists of officers, divisional boards, mines, etc., the names and addresses of former colliery owners in this country, and geographical and alphabetical lists of coal merchants, exporters, shippers and contractors. Other sections concern such matters as the Coal Industry Act, of 1949, mines regulations, blasting in collieries, the whereabouts and general data on the coal briquetting and coke-oven plants, and blast-furnace installations in Great Britain, a bibliography of literature on coal mining, lists of British Standard specifications, and a review of the coal-mining industry in 1952. Further useful features include membership of area boards and divisions of the British Electricity Authority and the Gas Council, and a "Who's Who" in the coal industry.

BOOKS RECEIVED.

United States National Bureau of Standards. Applied Mathematics Series No. 22. *Probability Tables for the Analysis of Extreme-Value Data.* The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 25 cents.]

United States Bureau of Mines. Bulletin No. 521. *Barrier Pillars in the Western Middle Field Anthracite Region of Pennsylvania.* By S. H. ASH, D. O. KENNEDY, H. B. LINK and W. M. ROMISCHER. The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 1 dol.]

Modern British Aeroplanes. By CHARLES GARDNER. Temple Press, Limited, Bowling Green-lane, London, E.C.1. [Price 9*s.* 6*d.* net.]

Grundwerte für das Cross-Verfahren. By DIPL.-ING. RUDOLF BARTH. Wilhelm Ernst und Sohn, Hohenzollerndamm 169, Berlin-Wilmersdorf, Germany. [Price 10 D.M.]; and Lange, Maxwell and Springer, Limited, Maxwell House, 242, Marylebone-road, London, N.W.1. [Price 17*s.* 6*d.*]

Handbuch der Vakuumtechnik. By E. L. HOLLAND-MERTEN. Third revised and enlarged edition. Vet. Wilhelm Knapp Verlag, Mühlweg 19, Halle (Saale). [Price 37 D.M.]

Basic Engineering Metallurgy. Theories, Principles and Applications. By PROFESSOR CARL A. KEYSER. Macdonald and Company (Publishers), Limited, 16, Maddox-street, London, W.1. [Price 60*s.* net.]

United States National Bureau of Standards. Circular No. 543. *Reference Data for Orienting Quartz Plates by X-Ray Diffraction.* The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 15 cents.]

Hydraulic Research in the United States. U.S. National Bureau of Standards Miscellaneous Publication No. 208. The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 1.25 dols.]